APPENDIX V-GRYN LITERATURE REVIEW

Greater Yellowstone Network Literature Review
Version 2
May 30, 2003

AIR

Malm, W.C. 2002. Introduction to Visibility. Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, 68pp.

Abstract in Progress (1)

National Atmospheric Deposition Program. 2002. National Atmospheric Deposition Program 2001 Annual Summary, NADP Data Report, 2002-01. Illinois State Water Survey. Champaign, Ill. Http://napd.sws.uiuc.edu/lib/

Abstract in Progress (334)

National Park Service, Air Resources Division, Air Quality in the National Parks, Monograph of the NPS-Air Resources Division, October 2002.

The report summarizes what has been learned from the NPS air quality research and monitoring program (1978-1987). The report provides information from the visibility, biological effects, and ambient air quality research and monitoring programs. Superintendents, resource managers, and interpreters can use the report as a reference for resource management planning and interpretive programs. The report helps individuals to have a better understanding of how air pollution is affecting park resources and values, on a service wide, regional and park specific basis. This report is currently in its Second Edition. (2)

Peterson, D.L., M.J. Arbaugh and L.J. Robinson. 1993. Effects of ozone and climate on ponderosa pine (Pinus ponderosa) growth in the Colorado Rocky Mountains. Can. J. For. Res. 23: 1750-1759.

Long-term radial growth trends of ponderosa pone (Pinus ponderosa var. scopulorum) were studied in second-growth stands in the Front Range of the Colorado Rocky Mountains to determine if there has been any impact from oxidant air pollution. Although ozone concentrations are relatively high at some locations, visible pollutant injury was not found in any trees. Time series of basal area increments are generally homogenous within stands. Concurrent periods of increasing and decreasing growth can be found in stands throughout the Front Range, which indicates that there are temporal growth trends at the regional level. Most of these trends appear to be related to the effects of stand dynamics and climate. Correlation analysis with climatic variables indicates that soil moisture supply is the dominant factor controlling interannual variation of basal area growth. Palmer hydrological drought index is highly correlated (positively) with growth during the simmer months; total precipitation in spring is positively correlated with growth, and mean temperature in spring is negatively correlates with growth. There are no recent changes in growth trends that might be associated with elevated levels of ambient ozone in the Front Range. (Abstract by Arbaugh and Robinson as printed in Canadian Journal of Forest Research). (3)

Peterson, D.L., T.J. Sullivan, J.M. Eilers, S. Brace, 1998. Assessement of Air Quality and Air Pollutant Impacts in National Parks of the Rocky Mountains and Northern Great Plains. Air Resources Division, Denver, CO,

For Yellowstone (pp. V1-V36), gives general description, monitoring and research activities, air quality related values, and research and monitoring needs. Includes lists of plant and lichen species useful as air quality indicators. (4)

Turk, J., H. Taylor, G. Ingersoll, K. Tonnessen, D. Clow, M. A. Mast, D.Campbell and J. Melack. "Major ion chemistry of the Rocky Mountain snowpack, USA", Atmospheric Environment 35 (2001): 3957-3966, 2001.

During 1993-97, samples of the full depth of the Rocky Mountain snowpack were collected at 52 sites from northern New Mexico to Montana and analyzed for major-ion concentrations. Concentrations of acidity, sulfate, nitrate, and calcium increased from north to south along the mountain range. In the northern part of the study area, acidity was most correlated (negatively) with calcium. Acidity was strongly correlated (positively) with nitrate and sulfate in the southern part and for the entire network. Acidity in the south exceeded the maximum acidity measured in snowpack of the Sierra Nevada and Cascade Mountains. Principal component analysis indicates three solute association were characterize as: (1) acid (acidity, sulfate, and nitrate), (2) soil (calcium, magnesium, and potassium), and (3) salt (sodium, chloride, ammonium). Concentrations of acid solutes in the snowpack are similar to concentrations in nearby wetfall collectors, whereas, concentrations of soil solutes are much higher in the snowpack than in wetfall. Thus, dryfall of acid solutes during the snow season in negligible, as is gypsum from soils. Snowpack sampling offers a cost-effective complement to sampling the wetfall in areas where wetfall is difficult to sample and where the snowpack accumulates throughout the winter. (Abstract by Turk et al as printed in Atmospheric Environment). (5)

BIODIVERSITY

Hansen, A.J., A. Gallant, J.J. Rotella, D. Brown. Natural and Human Drivers of Biodiversity in the Greater Yellowstone Ecosystem

Abstract in Progress (6)

Langner, L. L., and C. H. Flather. 1994. Biological diversity: status and trends in the United States. U.S. Forest Service General Technical Report RM-244. 21 pp.

The Nature Conservancy (1975) issued a report on natural diversity, almost 20 years ago, that indicated a rapid loss of ecosystems and communities in the United States. The report emphasized the reliance of society on ecological ecosystems, and the need to protect natural areas that support species and natural communities. Today the same concerns are being expressed in terms of biological diversity. This report summerizes information available that can provide evidence about the status and trends in biological diversity in the United States. A literature review of the topic has been handled elsewhere (Myers 1983, Wilson 1988a, Wilson 1992). (Introduction by Langner and Flather as printed in GTR RM-244) (8)

Whittaker, R.J., Willis, K.J., and Field, R. (2001) Scale and species richness : towards a general, hierarchical theory of species diversity. Journal of Biogeography, 28(4), pp. 453-470.

Aim: Current weaknesses of diversity theory include: a failure to distinguish different biogeographical response variables under the general heading of diversity; and a generalfailure of ecological theory to deal adequately with geographical scale. Our aim is toarticulate the case for a top-down approach to theory building, in which scale is addressed explicitly and in which different response variables are clearly distinguished. Location The article draws upon both theoretical contributions and empirical analyses from all latitudes, focusing on terrestrial ecosystems and with some bias towards (woody) plants. Methods: We review current diversity theory and terminology in relation to scale of applicability. As a starting point in developing a general theory, we take the issue of geographical gradients in species richness as a main theme and evaluate the extent to which commonly cited theories are likely to operate at scales from the macro down to the local. Results: A degree of confusion surrounds the use of the terms alpha, beta and gamma diversity, and the terms local, landscape and macro-scale are preferred here as a more intuitive framework. The distinction between inventory and differentiation diversity is highlighted as important as, in terms of scale of analysis, are the concepts of focus and extent. The importance of holding area constant in analysis is stressed, as is the notion that different environmental factors exhibit measurable heterogeneity at different scales. Evaluation of several of the most common diversity theories put forward for the grand clines in species richness, indicates that they can be collapsed to dynamic hypotheses based on climate or historical explanations. The importance of the many ecological/biological mechanisms that have been proposed is evident mainly at local scales of analysis, whilst at the macro-scale they are dependent largely upon climatic controls for their operation. Local communities have often been found not to be saturated, i.e. to be non-equilibrial. This is argued, perhaps counter-intuitively, to be entirely compatible with the persistence through time of macro-scale patterns of richness that are climatically determined. The review also incorporates recent developments in macroecology, Rapoport's rule, trade-offs, and the importance of isolation, landscape impedance and geometric constraints on richness (the mid-domain effect) in generating richness patterns; highlighting those phenomena that are contributory to the Ærst-order climatic pattern, and those, such as the geometric constraints, that may confound or obscure these patterns. Main conclusions: A general theory of diversity must necessarily cover many disparate phenomena, at various scales of analysis, and cannot therefore be expressed in a simple formula, but individual elements of this general theory may be. In particular, it appears possible to capture in a dynamic climate-based model and `capacity rule', the form of the grand cline in richness of woody plants at the macro-scale. This provides a starting point for a top-down, global-to-local, macro-to-micro scale approach to modelling richness variations in a variety of taxa. Patterns in differentiation/endemicity, on the other hand, require more immediate attention to historical events, and to features of geography such as isolation. Thus, whilst we argue that there are basic physical principles and laws underlying certain diversity phenomena (e.g. macro-scale richness gradients), a pluralistic body of theory is required that incorporates dynamic and historical explanation, and which bridges equilibrial and nonequilibrial concepts and ideas. (Abstract by Whittaker as printed in the Journal of Biogeography). (9)

Wilson, E.O. 1988. Biodiversity. Harvard University, Editor; National Academy of Sciences/Smithsonian Institution

Abstract in Progress (10)

BIOLOGICAL INVENTORIES

Stohlgren, T. J., J. F. Quinn, M. Ruggiero, and G. Waggoner. 1995b. Status of biotic inventories in U.S. national parks. Biological Conservation 71:97-106.

It is the policy obligation of the National Park Service to conduct baseline inventories of natural resources preserved in its 32 million hectare National Park System. We evaluated the status of natural resources information in 252 national parks and monuments: those park units that contain significant natural resources. Results show that few parks contain relatively complete systematic inventories for any major plant or animal group. Better information on species occurrence is available for vascular plant, mammals and birds than for other taxa (reptiles, amphibians and fish). Although most parks have compiled species lists for at least some taxa, the majority (>80%) of the lists are reported to be less than 80% complete in their species, geographic, and ecological (community type) coverage. An earlier study of 40 parks in California, Arizona, Nevada, and Hawaii found that information on terrestrial invertebrates, aquatic invertebrates, and non-vascular plants was generally poor or non-existent. Thus, the National Park Service presently knows little about the biological diversity in national parks. Spatially explicit data on park resources are also limited. While 43.28 and 24% of the 252 parks surveyed had maps of vegetation, soils and geology, respectively, none of these maps appears to have been systematically checked for accuracy after their creation. If parks are to serve as baselines to measure environmental change, there is an urgent need (1) to develop strategic plans to rank inventory needs in the National Park System; and (2) to design and conduct biological inventory programs to bring all parks to an acceptable level of resource awareness. (Abstract by Stohlgren et al as printed in Biological Conservation). (11)

BIRD

Diem, K. L. , Pugesek, B. H. . 1994. American white pelicans at the Molly Islands, in Yellowstone National Park: Twenty-two years of boom-and-bust breeding, 1966-1987. Colonial Waterbirds. 17 2: 130-145.

Systematic monitoring of nesting and fledging of American white pelicans (Pelecanus erythrorhynchos) breeding on the Molly Islands of Yellowstone Lake was carried on for 20 years between 1966 and 1987. The mean number of pelicans fledged during those years was 214 (plus or minus 196 SD). In five of those years the number of pelicans fledged was at or near zero. In six other years, the number of young pelicans fledged ranged from 302-650, with four of those years producing record numbers of successfully fledged young. This paper chronicles the dynamics of the Molly Island white pelican population and seeks to determine if a reliable status assessment of the white pelican population on the Molly Islands could be obtained. (13)

Diem, Kenneth L., Montopoli, George, Anderson, Donald A. 1991. Canada geese of Jackson Hole, some aspects of population and habitat changes. University of Wyoming, Jackson, WY.

This study addresses the population dynamics, factors influencing goose habitat and population productivity, as well as the maintenance of optimal levels of Canada geese in Jackson Hole, Wyoming during the period 1965-1989. Mean breeding pairs increased 54% from 117 pairs in 1965-1989. Mean clutch size in 1979-1980 was 5.0 compared to 5.2 for 1962-64 with mean brood sizes being 4.0 and 4.7, respectively. Thus maximum capacity for Canada goose production. Analysis of band recoveries indicated that the adjusted average annual mortality rate got geese banded in 1961-72 decreased by slightly more that 8% in comparison to those banded in 1956-60. Also, 1961-72 survival rates were higher in the 3rd years following banding and continued to be higher well beyond the 6th or 7th year than the survival rates of the 1956-1960 birds. Based on the 1977-78 data, the Canada goose breeding flock size in Jackson Hole was estimated to be 496 birds with a growth rate of 5-8% year. Ninety to 97% of hunter recoveries of banded geese are concentrated within Wyoming, Idaho, Utah, Arizona and California. Hunter harvests have not depressed the rate of population growth. Primary wintering areas for the geese are chiefly in southern California and Arizona. A 130% increase of private river float trips during the 10 years prior to 1989 presents a serious threat to the protective isolation historically provided the geese within Grand Teton National Park. A ceiling of 5000 commercial and 5000 private float trips per tear with trip permits required for all floaters would best serve all interests. A lottery drawing system for the allocation of private permits may be required. Snake River floater traffic is recommended to be lightest on the Flagg Ranch to Berry Creek sector, moderate on the Pacific Creek to Dead Man's Bar and heaviest on the Dead Man's Bar to Moos sector. Vegetated riverine island habitat provides some of the most desirable goose nesting and loafing habitat. Between 1949 and 1979, 19% (293 ha) of the vegetated island habitat of the Snake River of Jackson Hole was lost. The largest proportionate decrease (79.2 ha) was associated with the area of sectional flood control diking along the river below Wilson. At the same time there was a 37% (65.6 ha) increase in bare sand and grabble areas in the continuous flood control dike region. The prime Canada goose habitat in Jackson Hole extends laterally downstream from the Dime Creek-Upper Snake River junction to Jackson Lake, as well as along the western lake shore to the Berry Creek meadows. This habitat is particularly in need of management regulations which preserve their seasonal isolation from human activities. Long term aerial censusing of the goose breeding population should be continued on an annual basis with consistent procedures and experienced observers. Reliable flock composition and monitoring of population changes and the nature of the hunter harvest can only be determined through continued and consistent banding and color marking of geese in all seasons. (Abstract by Diem as printed in Canada Geese of Jackson Hole: Some Aspects of Population and Habitat Changes). (14)

Follett, D. Birds of Yellowstone and Grand Teton National Parks. Roberts Rinehart Publishing, Boulder, CO.

Abstract in Progress (15)

Hansen, A.J., and J.J. Rotella. 2000. Bird response to forest fragmentation. Pp. 201-219 in R. L. Knight, F.W. Smith, S.W. Buskirk, W.H. Romme, and W.L. Baker, eds. Forest Fragmentation in the Southern Rocky Mountains. University Press of Colorado, Boulder

Abstract in Progress (17)

Hayward, D. G., and J. Verner, editors. 1994. Flammulated, boreal, and great gray owls in the United States: a technical conservation assessment. U.S. Forest Service General Technical Report RM-253. 213 pp.

Flammulated (Otus flammeolus), boreal (Aegolius funereus), and great gray (Strix nebulosa) owls occur over a broad portion of North America and each is designated as a "sensitive species" in four or more USDA Forest Service regions. The insectivorous flammulated owl is a neotropical migrant requiring suitable wintering habitat in the extreme southwestern United State, Mexico, and Central America as well as breeding habitat in the mountains of the western United States. Flammulated owls breed predominately in yellow-pine Pinus ponderosa and Pinus jeffreyi) forest and are cavity nesters. The mature and older ponderosa pine forests used as breeding habitat by flammulated owls have changed during the past century due to fire management and timber harvest. In contrast, the boreal owl is a nomadic, small mammal specialist that occurs as an "island" species occupying subalpine and boreal forests. Movements among populations are probably important to boreal owl persistence, and coordinated management of disjunct populations in different Forest Service regions may be important. While the boreal owl's high altitude spruce-fir forest stands using existing raptor nests or tops of broken trees and snags for a nest platform. The species' requirement of a secure nesting platform leads to one potential ecological limitation on population size. Prey availability is the other factor thought to limit populations. Flammulated and boreal owls ma face significant conservation problems in the absence of conservation planning. Both owls are associated with older forest habitats. Limited research on the se species indicates that their demography and life history coupled with their fairly narrow habitat associations make them vulnerable to habitat change. Current forest management practices in many areas (i.e., stand replacement systems) remove quality habitat for these species. Therefore, on at least a local basis, persistence of these species could be in jeopardy, even in the short term. Long-term concerns are greater because the habitats that seem most important to these species require one to two centuries to regenerate. Furthermore, the population biology of both species necessitates across-region planning to facilitate effective conservation planning. Based on limited information, the persistence of great gray owl populations in the United States over both the short and long-term is more certain. Great gray owl foraging habitat use is more compatible with current forest management practices. Our understanding of the ecology and biology of these three species is not sufficient to produce a conclusive assessment of their conservation status. The enclosed assessments, however, give a sufficiently clear picture of each owl's status and the dynamics of important forest habitats to influence mangement and research decisions. It is clear that development of conservation strategies would aid management but current knowlegde of these species is insufficient to produce such a specific document. (Abstract by Hayward and Verner as printed in General Technical Report RM-253). (29)

Hutto, R.L. 1995. Composition of bird communities following stand-replacement fires in northern rocky Mountain U.S. A.) conifer forests. Conservation Biology 9(5):1041-1058.

During the two breeding seasons immediately following the numerous and widespread fires of 1988, I estimated bird community composition in each of the 34 burned-forest sites in western Montana and northern Wyoming. I detected an average of 45 species per site and a total of 87 species in the sites combined. A compilation of these data with bird-count data from more than 200 additional studies conducted across 15 major vegetation cover types in the northern Rocky Mountain region showed that 15 bird species are generally more abundant in early post-fire communities than in any other major cover type occurring in the northern Rockies. One bird species (Black-backed Woodpecker, Picoides arcticus) seems to be nearly restricted in its habitat distribution to standing dead forests created by stand-replacement fires. Bird communities in recently burned forests are different in composition from those that characterize other Rocky Mountain cover types (including early-succession clearcuts) primarily because members of three feeding guilds are especially abundant therein: woodpeckers, flycatchers, and seedeaters. Standing, fire-killed trees provided nest sites for nearly two-thirds of 31 species that were found nesting in the burned sites. Broken-top snags and standing dead aspens were used as nest sited for cavity-nesting species significantly more often than expected on the basis of their relative abundance. Moreover, because nearly all of the broken-top snags that were used were present before the fire, forest conditions prior to a fire (especially the presence of snags) may be important in determining the suitability of a site to cavity-nesting birds after a fire. For bird species that were relatively abundant in or relatively restricted to burned forests, stand-replacement fires may be necessary for longterm maintenance of their populations. Unfortunately, the current fire policy of public land management agencies does not encourage maintenance of stand-replacement fire regimes, which may be necessary for the creation of conditions needed by the most fire-dependant bird species. In addition, salvage cutting may reduce the suitability of burned-forest habitat for birds by removing the most important element-standing, fire-killed trees-needed for feeding, nesting, or both by the majority of bird species that used burned forests. (Abstract by Hutto as printed in Conservation Biology). (18)

McEneaney, T. et al. 1998. Greater Yellowstone Peregrine falcons: their trials, tribulations, and triumphs. Yellowstone Science, 6(2):16-21.

This article serves as an update on the "history, ecology and status" of the peregrine falcon (Falco peregrinus) in the Greater Yellowstone Ecosystem. A physical and biological description of the species including habitat, prey characteristics and breeding range is included. The article describes the history of abundance and of recovery efforts in the Greater Yellowstone that led to an encouraging 1997 report of 13 breeding pairs within the park who produced 25 young, with similar gains in Wyoming and Idaho. Authors state their consensus that the peregrine falcon is a recovered species that may be taken off the endangered species list but once de-listed will need to be monitored to ensure population security. (354)

McEneaney, T. M. . 1995. The common raven: an important Yellowstone predator. Pages 14 in No Editor/Author. Greater Yellowstone predators: Ecology and conservation in a changing landscape. Third Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Agenda and abstracts. National Park Service.

The role of the common raven (Corvus corax) as a predator in Yellowstone has been largely overlooked. The information presented here is based on 9 years of field observations recorded by the author. Three points are discussed in detail, namely raven morphology, food habits, and anecdotal observations on behavior and predation. Morphology and behavior suggest that common ravens are quintessential Yellowstone predators that specialize in killing small- to medium-sized prey. Seasonal availability and abundance of food plays an important role in raven predation. Ravens merit systematic study to better understand their functional ecological role in the Yellowstone ecosystem. (Abstract by McEneaney as printed in the Third Biennial Scientific Conference on the Greater Yellowstone Ecosystem Agenda and Abstracts). (19)

McEneaney, T.M. 2000. 2000 Yellowstone Bird Report. YNP, YCR?

Abstract in Progress (20)

Rotella, J. . 1995. Ecology of cavity-nesting birds: influence of disturbance type on density, breeding success and dispersal. Investigator's Annual Report.

Abstract in Progress (21)

Saveraid, E.H., D.M. Debinski, K. Kindscher, and M.E. Jakubauskas. 2001. A comparison of satellite data and landscape variables in predicting bird species occurrences in the Greater Yellowstone Ecosystem. Landscape Ecology 16(1):71-83.

We compare the accuracy of predicting the occurrence of 11 bird species in montane meadows of the Greater Yellowstone National Park ecosystem, in the states of Montana and Wyoming, USA. We used remotely sensed, landscape, and habitat data. The meadow type, as determined from the remotely sensed data, was highly correlated with abundances of six of the 11 bird species. Landscape variables significant in predicting occurrence were selected using a stepwise multiple regression for each bird species. These variables were then used in a multiple regression with the variable meadow type. As expected, the abundances of the generalist species (American Robin, Dark-eyed Junco, White-crowned Sparrow, Brewer's Blackbird, and Chipping Sparrow) were not strongly correlated with landscape variables or meadow type. Conversely, abundances of the Common Snipe, Common Yellowthroat, Lincoln's Sparrow, Savannah Sparrow, Vesper Sparrow, and Yellow Warbler were highly correlated with meadow type and landscape variables such as percent cover of willow (Salix spp.), graminoid, woody vegetation, sagebrush (Artemisia spp.), and graminoid and shrub biomass. The results from our study indicate that remotely sensed data are applicable for estimating potential habitats for bird species in the different types of montane meadows. However, to improve predictions about species in specific sites or areas, we recommend the use of additional landscape metrics and habitat data collected in the field. (Abstract by Saveraid et al as printed in Landscape Ecology). (22)

Schieck, J., et al. (1995). Effects of patch size on birds in old-growth montane forests. Conservation Biology, 9(5): 1072-1083.

Following habitat alteration or fragmentation, competition, parasitism, and predation from species that live in the new habitats may reduce the survival and reproductive success of species living in the original habitats. Negative influences from species that live outside the remnant patches are expected to be greater in small rather than in large remnant patches because more "external" species are expected to move through the centers of small remnant patches. We surveyed birds within remnant patches of old-growth montane forests on Vancouver Island, Canada, (1) to evaluate whether the richness and abundance of non-old-growth bird species were larger at the center of small rather than large patches and (2) to evaluate whether the opposite was true of old-growth bird species. More non-old-growth bird species were present at the center of small remnant patches of old growth than in large old-growth patches. We found no relationship, however, between patch size and richness or abundance of old-growth bird species at the center of remnant patches of old growth. This was true for old-growth species with open, cup-shaped nests and cavity nests. Old-growth birds may have been affected less in our study area than in other areas because they evolved within heterogeneous montane forests and interacted with non-old-growth species throughout their evolutionary histories or because the contrast between old-growth forests and logged areas was less than that between the forests and agricultural/urban areas that were surveyed in other studies. (Abstract by Schieck et al as printed in Conservation Biology). (23)

Sedgwick, J. A., and F.L. Knopf, 1990, Habitat Relationships and Nest Site Characteristics of Cavity-Nesting Birds in Cottonwood Floodplains: Journal of Wildlife Management, v. 54, p. 112-124.

We examined habitat relationships and nest site characteristics for 6 species of cavity-nesting birds--American kestrel (Falco sparverius), northern flicker (Colaptes auratus), red-headed woodpecker (Melanerpes erythrocephalus), black-capped chickadee (Parus atricapillus), house wren (Troglodytes aedon), and European starling (Sturnus vulgaris) -- in mature plains cottonwood (Populus sargentii) bottomland along the South Platte River in northeastern Colorado in 1985 and 1986. We examined characteristics of cavities, nest trees, and the habitat surrounding nest trees. Density of large trees (>69 cm dbh), total length of dead limbs ≥10 cm diameter (TDLL), and cavity density were the most important habitat variables; dead limb length (DLL), dbh, and species were the most important tree variables; and cavity height, cavity entrance diameter, and substrate condition at the cavity (live vs. dead) were the most important cavity variables in segregating cavity nesters along habitat, tree, and cavity dimensions, respectively. Random sites differed most from cavity-nesting bird sites on the basis of dbh, DLL, limb tree density (trees with ≥1 m dead limbs ≥ 10 cm diameter), and cavity density. Habitats of red-headed woodpeckers and American kestrels were the most unique, differing most from random sites. Based on current trends in cottonwood demography, densities of cavity-nesting birds will probably decline gradually along the South Platte River, paralleling a decline in DLL, limb tree density, snag density, and the concurrent lack of cottonwood regeneration. (Abstract by Sedgwick and Knopf as printed in the Journal of Wildlife Management). (655)

Swenson, J. E. , Alt, K. L. , Eng, R. L. . 1986. Ecology of bald eagles in the greater Yellowstone ecosystem. Wildlife Monographs. 95: 1-46.

The ecology of the bald eagle (Haliaeetus leucocephalus) was studied from 1972 to 1982 in the Greater Yellowstone Ecosystem in northwestern Wyoming and adjacent Idaho and Montana. This population consisted of 3 ecologically, but not genetically, distinct units: the Yellowstone Unit (YU), the Continental Unit (CU), and the Snake Unit (SU). The population probably was stable at 30-31 breeding pairs from 1960 to 1970, but increased exponentially to 50 known breeding pairs from 1971 to 1982. Breeding bald eagles were adaptable in selecting breeding areas. A stable food source, which was available from early spring, appeared to be the most important factor in breeding area selection. (24)

Taylor, D.L., Barmore, W.J.=, Jr. 1980. Post-fire succession of avifauna in coniferous forests of Yellowstone and Grand Teton National Parks, Wyoming. U-S-D-A-For-Serv-Gen-Tech-Rep-INT-U-S-Intermt-For-Range-Exp-Stn. 86: 130-145.

Yellowstone and Grand Teton National Parks have been zoned to allow certain natural fires to burn until they self-extinguish. The effect of these natural fires on avifauna in the two parks is reported in this paper.

Breeding birds populations in burned lodgepole or spruce-fir-lodgepole pine forest of the following post0fire ages are analyzed: MODERATE BURN 1, 2, 3 years; SEVERE BURN 1, 2, 3, 5, 7, 11, 13, 17, 25, 29, 43, 44, 45, 57, 61, 111, 115, 300, 304 years; UNBURNED SPRUCE-FIR WITH SOME LODGEPOLE PINE, and UNBURNED SPRUCE-FIR. Highest populations and greatest biomass occurred from 5-29 years post-fire. Bird density, species composition, and diversity on moderately burned spruce-fir-lodgepole were more like those on unburned spruce-fir than on other seral stages. Greatest biomass ground-seed feeding categories occurred where the forest canopy has not closed. Biomass of foliage-insect and timber-searching was greatest where the forest canopy had closed. Canopy closure affected avifuana more than fire did. (Abstract by Taylor and Barmore as printed in General Technical Report INT-86). (25)

USFS. Status and management of Neotropical migratory birds. U.S. Forest Service General Technical Report RM-229.

Abstract in Progress (12)

Wiens, J.A., and J.T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecol. Monogr. 51(1)21-24.

Abstract in Progress (32)

Wolf, Carl E. 1990. Birding checklist for the Pryor Mountains and Bighorn Canyon.

Abstract in Progress (26)

CARNIVORE

Bangs, E. E. , Fritts, S. H. . 1996. Reintroducing the gray wolf to central Idaho and Yellowstone National Park [correction]. Wildlife Society Bulletin. 24(3): 402-413.

Plans to reintroduce the grey wolf to central Idaho and Yellowstone National Park attracted considerable controversy. Some people believed that the wolves would have a negative impact on agriculture in the region, while others felt that wolves were already in these areas or would soon return there, and that wolf habitat should be given greater protection. Nevertheless, the first wolves were released into central Idaho on Jan 14, 1995. Wolves reintroduced in the state travelled extensively, mostly going north, but most stayed on public land within the core reintroduction area. There were seven groups released in Yellowstone National Park, and all expect one breeding pair remained together. (Abstract by Bangs as printed in Wildlife Society Bulletin). (33)

Berger, J. 1998. Future Prey: Some Consequences of Losing and Restoring Large Carnivores. Pp. 80-100. In: Behavioral Ecology and Conservation Biology. (Ed, T, Caro). Oxford University Press .

Abstract in Progress (34)

Blanchard, B. M., and R. R. Knight. 1996. Effects of wildfire on grizzly bear movements and foraging strategies. Pages 117-122 in J. M. Greenlee, editor. Proceedings of the second biennial scientific conference on the Greater Yellowstone Ecosystem. International Association of Wildland Fire, Fairfield, Washington.

Forty-four radio-telemetered grizzly bears (Ursus arctos horribilis) were located 867 times during 1989-92 within Yellowstone National Park following extensive wildfires in 1988. Pooled locations indicated avoidance of burned sites during 1989, especially by females with cubs-of-the-year, but not during subsequent years. On the average, individual grizzly bears were located in burned and unburned habitats in proportion to their availability within each bear's annual range. Rates of movement were lower than those recorded prior to the fires, indicating adequate native food supplies. Feeding habits at burned sites differed significantly from those recorded at unburned sites. Short-term effects of the fires were beneficial to grizzly bears largely because of increased production of diet items such as forb foliage and tuberous root crops in burned habitats. (Abstract by Blanchard and Knight as printed in the Proceedings of the Second Biennial Scientific Conference on the Greater Yellowstone Ecosystem). (35)

Browne-Nunez, C., and J.G. Taylor, 2002, Americans' Attitudes Toward Wolves and Wolf Reintroduction: an annotated bibliography: Information and Technology Report USGS/BRD/ITR-2002-0002, 15 p.

Abstract in Progress (36)

Buskirk, S. W. <Steven W. >. "Mesocarnivores of Yellowstone." In CarnivoresinEcosystems, ed. Tim W. Clark, p. 164-87. New Haven [Conn.]: Yale University Press,1999.

Abstract in Progress (37)

Cole, G.F. 1976. Management involving Grizzly and Black Bears in Yellowstone National Park. 1970-1975. Natural Resources Report No. 9. National Park Service, U.S. Department of the Interior, Washington, DC.

A management program to 1) maintain the grizzly bear (Ursus arctos) and black bear (U. americanus) populations in Yellowstone National Park under natural conditions and 2) reduce bear injuries to humans is evaluated by testing hypotheses that could be rejected by inconsistent data. Management involved eliminating sources of unnatural food that concentrated bears in and near developed areas, controlling bears that persisted in seeking food in such areas, regulating camping and hiking, and informing park visitors of appropriate precautions and the consequences of feeding bears. The author concluded that the management program was accomplishing its intended objectives. (38)

Copeland, J. 1996. Biology of the wolverine in central Idaho. M.S. Thesis, University of Idaho, Moscow. 138 pp.

I determined wolverine (Gulo gulo) presence, ecology, spatial characteristics, movement, demographics, social structure, and habitat use in central Idaho from 1992-1995. My study area encompassed approximately 8,000 km2 of primarily roadless and statutory wilderness habitats. The study area was characterized by montane coniferous forests at lower elevations, to high elevation subalpine habitats associated with talus scree and non-forested mountain tops. Nineteen wolverines were captured and instrumented with intraperitoneal implant transmitters. I monitored wolverines weekly, by ground and aerial telemetry, collecting 1,050 relocations. Annual home ranges of resident adults averaged 384 km2 for females and 1,582 km2 for males. Adult home ranges were segregated by sex, with female home ranges overlapping <10% and male home ranges overlapping <15%. Offspring of both sexes remained associated with the natal area for up to 2 years corresponding with sexual maturation. Juveniles and subadults interacted with resident kin, including their mother, the resident male, and siblings. Evidence of resident adult wolverine associating with subadult wolverine was previously undescribed. Periods of association lasted as long as 7 days with individuals traveling together or localizing at foraging sites. The extended association of subadults and adults may be related to the highly dispersed nature of food resources and may account for large home range sizes of resident females. Adult male home ranges encompassed up to 3 female home ranges. Snow-tracking sessions were conducted to document scent-marking and foraging behavior. Food resources were widely dispersed but consistent in timing and presence which may produce traditional foraging routes. Such sites were revisited within a season of use and between years and were shared within kinship groups. Urination was the primary method of scent-marking observed during this study. The reproductive rate for 4 adult females was less than 1 kit/female/year.

Females used secluded high elevation cirque basins for natal den sites. Human disturbance at maternal dens resulted in den abandonment but not kit abandonment. Kits remained with the adult female for approximately 3 months subsequent to weaning at 9 to 10 weeks of age. Females commonly left dependent kits at rendezvous sites comprised of large boulder talus or riparian areas associated with mature overstory and dense timber deadfall. Boulder talus associated with subalpine habitats was also used for resting and foraging sites. Four male wolverines dispersed at sexual maturity, with 2 emigrating distances greater than 185 km. Two of these individuals appeared to establish at the new location while the other 2 returned to the study area. Seven wolverines died during the study, with predation accounting for 43% of the mortality. Distinct seasonal shifts in elevation use were recorded, with higher elevational talus/rock cover types preferred during summer months, and montane coniferous forest cover types preferred during winter. Wolverines avoided lowland grass/shrub and ponderosa pine (Pinus ponderosa) cover types. Movement to lower elevations during winter months may be correlated with increased presence of carrion attributable to the fall big game hunting seasons. Ungulate species including mule deer (Odocoileus hemionus), elk (Cervus elaphus), moose (Alces alces), and domestic cow (Bos bos) and horse (Equus sp.) were present at similar proportions in both summer and winter scat and foraging site collections. Other prey items included 5 species of carnivores: 12 rodent species, including 5 sciurids; and 1 lagomorph species. Avian species constituted 4.9% of species occurrences while insects, primarily ants, occurred at 5.9%. (Abstract by J. Copeland. As printed in. M.S. Thesis) (39)

Crabtree, R.., and J.W. Sheldon. 1999. the ecological role of coyotes on Yellowstone's northern range. Yellowstone Science 7(2): 15-23.

Discusses studies initiated in 1989, 6 years prior to wolf reintroduction. Covers social systems, reproduction, pup survival, population density and territory size, food habits, ecological relations between coyotes and prey species, fire impacts on coyotes, pack size and population regulation, and the return of the wolves. (40)

Craighead, John Johnson, Jay S. Sumner, and John A. Mitchell. The Grizzly Bears of Yellowstone: Their Ecology in the Yellowstone Ecosystem, 1959-1992. Washington DC:Island Press, 1995.

Abstract in Progress (41)

Gese, E.M., R.L. Ruff and R.L. Crabtree. 1996. Intrinsic and extrinsic factors influencing coyote predation of small mammals in Yellowstone National Park. Canadian Journal of Zoology. 74:784-97.

Examines factors influencing predation: age, sex, social status, snow depth and hardness, temperature, cloud cover, wind speed and habitat. Findings indicate young, inexperienced coyotes detected and attacked small mammals at a higher rate than did older animals. (396)

Gese, E.M., R.L. Russ, and R.L. Crabtree. 1996. Social and nutritional factors influencing the dispersal of resident coyotes. Anim. Behav., 52: 1025-1043.

Five resident packs were observed from January 1991 to June 1993 to determine what factors influence whether a coyote will remain in its natal pack or disperse. Lower ranking individuals were likelier to disperse and showed lower success at catching small mammals. (42)

Gunther, K., M. T. Bruscino, S. L. Cain, J. Copeland, K. Frey, M. A. Haroldson, and C. C. Schwartz. 2002. Grizzly bear-human conflicts in the Yellowstone Ecosystem. Ursus (in press).
Abstract in Progress (43)

Gunther, K.A. 1994. Bear Management in Yellowstone National Park, 1960-1993. Int. Conf. Bear Res. and Manage. 9(1):549-560
"From 1931 through 1959, an average of 48 people per year were injured by bears in Yellowstone National Park (YNP). In 1960, YNP implemented a bear management program designed to reduce the number of bear-caused human inures and property damages occurring with YNP and to re-establish bears in a natural state....After 10 years (1960-1969) of the program, 332 nuisance black bears (Ursus americanus) and 39 nuisance grizzly bears (Ursus arctos horribilis) had been removed from the population. ..In 1970, YNP initiated a new, more intensive bear management program with the objectives of restoring the grizzly and black bear populations to subsistence on natural forage and reducing the number of bear caused injuries to humans." (44)

Haroldson, M.A., M.A, Ternent, K.A. Gunther, and C.C. Schwartz. In Press. Grizzly bear denning chronology and movements in the Greater Yellowstone Ecosystem. Ursus 13:
Den entrance and emergence dates of grizzly bears (Ursus arctos) in the Greater Yellowstone Ecosystem are important to management agencies that wish to minimize impacts of human activities on bears. Current estimates for grizzly bear denning events use data that were collected from 1975-80. We update these estimates by including data obtained from 1981-99. We used aerial telemetry data to estimate week of den entry and emergence by determining the midpoint between the last known active date and the first known date denned, as well as the last known date denned and the first known active date. We also investigated post emergence movement patterns relative to den locations. Mean earliest and latest week of den entry and emergence were also determined. Den entry for females began during the fourth week in September, with 90% denned by the fourth week of November. Earliest den entry for males occurred during the second week of October, with 90% denned by the second week of December.
Mean week of den entry for known pregnant females was earlier than for males. Earliest week of den entry for known pregnant females was earlier than for other females and males. Earliest den emergence for males occurred during the first week of February, with 90% of males out of dens by the fourth week of April. Earliest den emergence for females occurred during the third week of March; by the first week of May, 90% of females had emerged. Male bears emerged from dens earlier than females. Denning period differed among classes and averaged 171 days for females that emerged from dens with cubs, 151 days for other females, and 131 days for males. Known pregnant females tended to den at higher elevations and following emergence remained at
higher elevations until late May. Females with cubs remained relatively close (<3 km) to den sites until the last 2 weeks in May. Timing of denning events was similar to previous estimates for this and other grizzly bear populations in the southern Rocky Mountains. (45)

Heinemeyer, Kimberly S., Aber, Bryan C., Doak, Daniel F. 2001. Aerial Surveys for Wolverine Presence and Potential Winter Recreation Impacts to Predicted Wolverine Denning Habitats in

the Southwestern Yellowstone Ecosystem."
http://gis.ucsc.edu/Projects/gulo2000/wolverine_report2000.pdf
Abstract in Progress (377)

Johnson, K.A. and R.L. Crabtree. 1999. Small prey of carnivores in the Greater Yellowstone Ecosystem. Pp. 239-264 in Carnivores in Ecosystems: the Yellowstone Experience, T.W. Clark, A.P. Curlee, S.C. Minta, and P.M. Kareiva, eds. New Haven, CT: Yale University

"This chapter integrates information from a review of the literature and esults of a cooperative small mammal study on the Northern Range of Yellowstone National Park, hereafter called the Northern Range Small Mammal Study. This study was initiated in YNP in 1990 and has been continued since 1993 by Yellowstone Ecosystem Studies. We summarize small-mammal habitat relations, community structure, and landscape patterns (including the effects of disturbace) in the GYE, and we discuss relavant carnivore food habits studies as they pertain to small mammals. We analyze the implications of current knowledge about small prey for carnivore conservation and make recommendations for small-mammal research." (Summary by Johnson and Crabtree as printed on first page of chapter) (46)

Keiter, R. B. . 1991. Observations on the future debate over "delisting" the grizzly bear in the Greater Yellowstone Ecosystem. Environmental Professional. 13 3: 248-253.

With grizzly bear population numbers now on the upswing in the Greater Yellowstone Ecosystem (USA), federal and state wildlife managers are suggesting tentatively that the bear might be "delisted" from the Endangered Species Act(ESA) in the not-too-distant future if current trends continue. Under the ESA, rigorous legal requirements must be met before a protected species is delisted. A Yellowstone delisting effort most likely would be based upon the grizzly bear delisting effort that currently is pending in the Northern Continental Divide Ecosystem in Montana. Biological and legal conditions in the Greater Yellowstone Ecosystem, however, differ quite significantly from those prevailing in the Northern Continental Divide Ecosystem. Indeed, agency officials have yet to answer several critical biological questions concerning the Yellowstone bear population and the security of its habitat, as well as important legal questions concerning how the bear and its habitat will be protected in the absence of state ESA or NEPA laws. Until these questions are answered, delisting discussions must be tempered with caution. (47)

Logan, K. A. and L. L. Irwin. 1985. Mountain lion habitats in the Big Horn Mountains, Wyoming. Wildl. Soc. Bull. 13:257-262.

Food habits of mountain lions (Felis concolor) have been quantified (Hornrocker 1970, Spalding and Lesowski 1971, Shaw 1977, Toweill and Meslow 1977, Ackerman et al. 1984), but relatively little is known about lion use of vegetation and topography. Seidensticker et al. (1973) and Hemker (1982) described habitat at scratch sites, and Berg et al. (1983) calculated density of lion sightings for 16 Kulchler (1964) potential vegetation types in Wyoming. This paper quantifies lion habitat use patterns by testing the hypothesis that lions use vegetation and terrain features in proportion to availability. (Abstract by Logan and Irwin as printed in Wildlife Society Bulletin). (48)

Logan, K. A. and L. L. Sweanor. 2001. Desert puma: evolutionary ecology and conservation of an enduring carnivore. Island Press, Washington, DC. 448pp.
Abstract in Progress (49)

Mattson, D. J. , Gillin, C. M. , Benson, S. G., Knight, R. R. . 1991. Bear feeding activity at alpine insect aggregation sites in the Yellowstone Ecosystem. Canadian Journal of Zoology. 69: 2430-2435.
"Bears (Ursus arctos horribilis and U. americanus) were observed from aircraft on or near alpine talus in Wyoming and Montana during 15 June-15 September 1981-89. Bears fed on insect aggregations at 6 known and 12 suspected alpine talus sites, disproportionately more at elevations above 3350 m, on slopes >30 degrees and on south- and west-facing aspects. While at these sites, bears almost exclusively ate invertebrates, typically Euxoa auxiliaris. Subadult grizzly bears (U. a. horribilis) appeared to be underrepresented at the sites and proportionate representation of adult females with young decreased between 15 June and 15 September. Overall, observations of bears at these sites increased between 1981 and 1989. It is suggested that alpine insect aggregations are an important food source for bears, especially in the absence of high quality foraging alternatives in July and August of most years." (50)

Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1991. Food habits of Yellowstone grizzly bears. Canadian Journal of Zoology 69:1619-1629.
Food habits of grizzly bears were studied for 11 years in the Yellowstone area of Wyoming, Montana, and Idaho by analyzing scats. Ungulate remains constituted a major portion of early-season scats, graminoids of May and Jun scats, and whitebark pine seeds of late-season scats. Berries composed a minor portion of scats during all months. The diet varied most among years during May, Sep, and Oct, and was most diverse during Aug. Defecation rates peaked in Jul and were low in Apr through Jun. Among-years differences in scat content were substantial; estimates of average scat composition took 4-6 years to stabilize. Major trends in diet were evident and reflected long-term variation. We suggest that long-term studies are necessary to adequately document bears' food habits in variable environments; the Yellowstone grizzly bears' diet varied with seasonal and yearly availability of high-quality foods, lack of berries and large fluctuations in the size of pine seed crops were major factors limiting bear density in the Yellowstone area. (51)

Mattson, D. J., S. Podruzny, and M. A. Haroldson. 2002. Consumption of fungal sporocarps by Yellowstone grizzly bears. Ursus 13:in press.
Abstract in Progress (52)

Murphy, K.M., P.I. Ross, and M.G. Hornocker. 1999. The ecology of anthropogenic influences on cougars. Pp. 77-102 in Carnivores in Ecosystems: the Yellowstone Experience, T.W. Clark, A.P. Curlee, S.C. Minta, and P.M. Kareiva, eds. New Have, CT: Yale University
Abstract in Progress (53)

Podruzny, S. R., D. P. Reinhart, and D. J. Mattson. 1999. Fire, red squirrels, whitebark pine, and Yellowstone grizzly bears. Ursus 11:131-138.

Whitebark pine (Pinus albicaulis) habitats are important to Yellowstone grizzly bears (Ursus arctos) as refugia and sources of food. Ecological relationships between whitebark pine, red squirrels (Tamiasciurus hudsonicus), and grizzly bear use of pine seeds on Mt. Washburn in Yellowstone National Park, Wyoming, were examined during 1984-86. Following large-scale fires in 1988, we repeated the study in 1995 –97 to examine the effects of fire on availability of whitebark pine seed in red squirrel middens and on bear use of middens. Half of the total length of the original line transects burned. We found no red squirrel middens in burned areas. Post-fire linear-abundance (no./km) of active squirrel middens that were pooled from burned and unburned areas decreased 27% compared to pre-fire abundance, but increased in unburned portions of some habitat types. Mean size of active middens decreased 54% post fire. Use of pine seeds by bears (linear abundance of excavated middens) in pooled burned and unburned habitats decreased by 64%, likely due to the combined effects of reduced midden availability and smaller midden size. We discourage any further large-scale losses of seed producing trees from management-prescribed fires or timber harvesting until the effects of fire on ecological relationships in the whitebark pine zone are better understood. (54)

Renkin, R. A. , Gunther, K. A. . 1995. Predicting grizzly bear mortality in relation to frontcountry developed areas in Yellowstone National Park. Pages 17-18 in No Editor/Author. Greater Yellowstone predators: Ecology and conservation in a changing landscape. Third Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Agenda and abstracts. National Park Service.

In 1986, a grizzly bear (Ursus arctos) mortality risk model was developed as part of the Environmental Impact Statement (EIS) for the Development Concept Plan (DCP) of the Fishing Bridge developed area. The model provided an estimate of the number of management transfers and, ultimately, bear mortalities that could be attributed to each of the 16 developed areas in the park for the subsequent 10-year period, 1987-96. Given that bear mortalities in relation to developed areas actually declined during the following decade, the model overestimated the number of transfers and mortalities that occurred across all developments from 1987-96. The model, however, accurately accounted for the 15 transfers and 3 mortalities that occurred at the 5 developments requiring bear management actions. Although restricted in utility to identifying point sources of continued mortality and the incremental risk associated with the placement of new facilities or the expansion of existing facilities within the park, the empirical model could supplement other efforts in quantifying mortality risk as part of a cumulative effects assessment for grizzly bears in the Greater Yellowstone Ecosystem (GYE). (Abstract by Renkin and Gunther as printed in Proceedings of the Third Biennial Conference on the Greater Yellowstone Ecosystem). (172)

Ripple, W. J., E.J. Larsen, R.A. Renkin, and D.W. Smith. 2001. Trophic cascades among wolves, elk and aspen on Yellowstone National Park's northern range. Biological Conservation. 102:227-234.

Quaking aspen (Populus tremuloides) biomass has declined in Yellowstone National Park (YNP) in the past century. We installed permanent belt transects (plots) for long-term monitoring of aspen stands both within and outside of established wolf pack territories on YNP's northern range to determine if reintroduced wolves are influencing elk browsing patterns and aspen regeneration through a trophic cascades interaction. Wolves may have an indirect effect on aspen regeneration by altering elk movements, browsing patterns, and foraging behavior (predation risk effects). Elk pellet groups, aspen sucker heights, and the percentage of browsed suckers were the variables used to measure differences in aspen stands in high and low wolf-use areas of the northern range. The aspen stands in the high wolf-use areas had significantly lower counts of elk pellet groups in the mesic upland steppe and the combined mesic upland steppe and riparian/wet meadow habitat types. Based on our pellet group results, it appears that elk foraging behaviors may have been altered by the increased risk of predation due to the reintroduction of the wolf. In the riparian/wet meadow habitat type, mean aspen sucker heights were significantly higher in the high wolf-use areas than in the low wolf-use areas. The percentage of browsed suckers in high and low wolf-use areas showed no significant differences in any of the habitat types. Considering the high browsing pressure in YNP aspen stands, it is uncertain whether the taller aspen suckers measured in the wolf-use areas will eventually join the aspen overstory. These permanent plots represent a valuable baseline data set to assess any current and future aspen regeneration responses to the reintroduction of wolves in YNP. (Abstract by Ripple et al as printed in Biological Conservation). (55)

Ruggiero, L. F., K. B. Aubry, S. W. Buskirk [and others]. 2000. Ecology and conservation of lynx in the United States. University Press of Colorado, Boulder, CO. 480pp.

Abstract in Progress (56)

Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, eds. The scientific basis for conserving forest carnivores. USDA Forest Service General Technical Report RM-254.184pp.

This cooperative effort by USDA Forest Service Research and the National Forest System assesses the state of knowledge related to the conservation status of four forest carnivores in the western United States: American marten, fisher, lynx, and wolverine. The conservation assessment reviews the biology and ecology of these species. It also discusses management considerations stemming from what is known and identifies information needed. Overall, we found huge knowledge gaps that make it difficult to evaluate the species' conservation status. In the western United States, the forest carnivores in this assessment are limited to boreal forest ecosystems. These forests are characterized by extensive landscapes with a component of structurally complex, mesic coniferous stands that are characteristic of late stages of forest development. The center of the distribution of this forest type, and of the forest carnivores, is the vast boreal forest of Canada and Alaska. In the western conterminous 48 states, the distribution of boreal forest is less continuous and more isolated so that forest carnivores and their habitats are more fragmented at the southern limits of their ranges. Forest carnivores tend to be wilderness species, are largely intolerant of human activities, and tend to have low reproductive rates and large spatial requirements by mammalian standards.
We must have information at the stand and landscape scales if we are to develop reliable conservation strategies for forest carnivores. Ecosystem management appears likely to be central to these conservation strategies. Complex physical structure associated with mesic late-successional forests will be important in forest carnivore conservation plans. Immediate conservation measures will be needed to conserve forest carnivore populations that are small and isolated. Additional forest fragmentation especially though clearcutting of contiguous forest may be detrimental to the conservation of forest carnivores, especially the fisher and marten. Specific effects will depend on the contest within which management actions occur. (Abstract by Ruggiero et al as printed in General Technical Report RM-254). (57)

Ruth, T.K. et al. 1999. Cougar-wolf interactions in Yellowstone National Park: competition, demographics, and spatial relationships. Annual technical rep., Hornocker Wildlife Institute, Yellowstone Cougars, Phas 11.

This article is a description of Phase II of Hornrocker Wildlife Institute's Yellowstone Cougar research to date. The purposes of this portion of the study were the quantification of cougar ecology with focus on relations between cougars and wolves and cougars and their prey in the Greater Yellowstone Ecosystem. Specific objectives are detailed in the report, as are results of the first three years of data collection. The project documented 161 cougar kills, 144 of them ungulates, 33% of which were then scavenged or taken over by other carnivores. Ground and aerial locations were obtained and then investigated to collect habitat information. Two cougars and two wolves have been radio-collared to collect location data at simultaneous times during the day. A future report is expected. (58)

Schullery, P., and L.H. Whittlesey. 1999. Greater Yellowstone carnivores: a history of changing attitudes. Pp. 11-49 in Carnivores in Ecosystems.

Abstract in Progress (59)

Schwartz, C.C., M.A. Haroldson, K.A. Gunther, and D. Moody. In Press. Distribution of grizzly bears in the Greater Yellowstone Ecosystem, 1990-2000. Ursus 13:

The Yellowstone grizzly bear (Ursus arctos horribilis) has been expanding its range during the past 2 decades and now occupies historic habitats that had been vacant. A current understanding of the distribution of grizzly bears within the ecosystem is useful in the recovery process, and to provide guidance to the state and federal land management agencies and state wildlife agencies of Idaho, Montana, and Wyoming as they prepare management plans. We used kernel estimators to develop distribution maps of occupied habitats based on initial sightings of unduplicated females (n = 300) with cubs of the year, information from radio-marked bears (n = 105), and locations of conflicts, confrontations, and mortalities (n = 1,235). Although each data set was constrained by potential sampling bias, together they provide insight into areas within the Greater Yellowstone Ecosystem (GYE) currently occupied by grizzly bears. The current distribution (1990-2000) extends beyond the recovery zone identified in the U.S. Fish and Wildlife Service Recovery Plan. Range expansion is particularly evident in the southern portion of the ecosystem in Wyoming. A comparison of our results from the 1990s to previously published distribution maps show an approximate increase in occupied habitat of 48% and 34% from the 1970s and 1980s, respectively. We discuss data biases and problems implicit to the analysis. (Abstract by Schwartz et al as printed in Ursus). (60)

Varley, John D. ; Brewster, Wayne G. Wolves for Yellowstone? : a report to the United States Congress /[Yellowstone National Park : National Park Service?], 1990-1992v. 1. Executive summary -- v. 2. Research and analysis -- v. 3. Executive summary –v. 4.

Abstract in Progress (61)

CLIMATE

Arnold, W. Energetics of Social Hibernation. C. Carey, et al., Editors. 1993. Life in the Cold: Ecological, Physiological, and Molecular Mechanisms, Westview Press: Boulder, CO. p. 65-80.

Abstract in Progress (86)

Balling, R.C., Jr., G.A. Meyer, and S.G. Wells. 1992. Climate change in Yellowstone National Park: is the drought related risk of wildifres increasing? Climate Change 22(1):35-45.

The increased frequency of wildfires in the U. S. has become a common prediction associated with the build-up of greenhouse gases. In this investigation, variations in annual wildfire data in Yellowstone National Park are compared to variations in historical climate conditions for the area. Univariate and multivariate analytical techniques reveal that a) summer temperatures in the Park are increasing, b) January-June precipitation levels are decreasing, and c) variations in burn area within the Park are significantly related to the observed variations in climate. Outputs from four different general circulation model simulations for 2 x CO2 are included in the analyses; model predictions for increasing aridity in the Yellowstone Park area are generally in agreement with observed trends in the historical climate records. (62)

Barnosky, A. D. , Hadly, E. A. . 1998. Effects of global climate change on mammalian communities: a prehistoric perspective. Pages 26 in No Editor/Author. Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts

We present data from four prehistoric climatic warming events in the Rocky Mountains to assess how ongoing global warming will affect mammalian communities. Responses to warming during Miocene (17 million years ago) are manifested as biogeographic range changes, adaptive radiations of new species, and extinction. Across middle Pleistocene glacial-interglacial transitions (about 800,000 years ago) the main responses are change in relative abundance and probably minor geographic range adjustments. Mammal communities spanning the late Pleistocene-Holocene transition (10,000 years ago) exhibit the same changes, with the added features of large-scale geographic range changes resulting in allopatry of previously sympatric species, and extinction of about 103 species. Limited evidence points to phenotypic change corresponding with climate change. On the short time scale exemplified by a late Holocene sequence, mammalian populations responded to the Medieval Warm Period (~1,200-650 years ago) by fluctuating in relative abundance (habitat specialist) and shifting biogeography margins of two species whose ranges barely reach into the area today. Pocket gophers (Thomomys talpoides) showed phenotypic, but not genetic, response to climate change. The data from these four warming events confirm that species respond individualistically to climatic change by (1) change or stasis in relative abundance, (2) altering geographic distribution, or (3) phenotypic response. These points of agreement transcend temporal scaling differences, and the same effects should be anticipated for future global warming. Extinction is evident in two of the four events and can also be expected in the current event. Speciation took place only in the event with the longest time scale (Miocene), and hence probably will not be important in maintaining diversity levels during the rapid climate change anticipated under current global warming scenarios. (Abstract by Barnosky and Hadly. As printed in Making a place for nature, seeking our place in nature: 125th Anniversary Symposium, May 11-23, 1998; agenda and abstracts.) (63)

Bartlein, P. J. ., Whitlock, C. , Shafer, S. L. . 1997. Future climate in the Yellowstone National Park region and its potential impact on vegetation. Conservation Biology. 11 3: 782-792.

The impact of global climate change in mountainous regions can't be predicted by simple upward displacements of existing vegetation zones. The output of a coarse-resolution climate

model incorporating a doubling of carbon dioxide showed a combination of elevational and directional range adjustments. New communities have no analogue in present day vegetation. (64)

Brooks, P.D., K. Tonnessen, S. Diamond, D. McKnight, P.S. Corn, E. Muths, and C. Ronca. Climate-mediated DOC concentrations control amphibian exposure to UV-B. Nature (Submitted)

Abstract in Progress (65)

Dirks, R. A. , Martner, B. E. . 1982. Climate of Yellowstone and Grand Teton National Parks. National Park Service, US Department of the Interior, National Park Service Occasional Paper Number 6, Washington, DC.

Climatological records were compiled and integrated to provide a summary of the climate of the Yellowstone and Grand Teton National Parks region. Semicontinuous records of daily maximum and minimum temperature and precipitation exist for several stations in the Parks, beginning as early as 1887. Wind, humidity, sunshine, and other data are very sparse. Tabulations of monthly means and extremes of temperature and precipitation are presented for several stations. Annual precipitation histories, wind velocity distributions, and other climate data are also provided. The complexity of the terrain and the wide range of elevations preclude the possibility that a single generalized description can accurately represent the climate at all localities in the region. However, the data presented typify most of the climatic regimes within the Parks. (67)

Engstrom, d.R., C. Whitlock, S.C. Fritz, and H.E. Wright, Jr. 1991. Recent environmental changes inferred from the sediments of small lakes in Yellowstone's northern range. J. Paleolimnology. 5:139-174.

Recent sediments of eight small lakes in the northern winter range of Yellowstone National Park were cored to examine stratigraphic records of past changes in limnology and local environment that might be attributed to grazing and other activities of elk, bison, and other large ungulates. Cores of undisturbed sediment were analyzed at close intervals to depths covering the last 100-150 years according to chronologies established by lead-210 dating. Pollen analyses were made to show change in regional vegetation, and diatom and geochemical analyses were made to reveal possible limnological changes resulting from soil erosion and nutrient input from the lake catchments. (68)

Fagre, D.B., D.L. Peterson, S.W. Running, P.E. Thornton, and C. Milesi. 2001. Climatic Variability, Ecosystem Dynamics, and Disturbance in Mountain Protected Areas. Global Change Open Science Conference: Challenges of a Changing Earth, July 10-13, 2001, Amsterdam, The Netherlands

Abstract in Progress (69)

Fastie, C.L., S.T. Gray, and J.L. Betancourt. In preparation. Late Holocene climate variation inferred from tree-rings in the Bighorn Mountains of Wyoming.

Abstract in Progress (70)

Graumlich, L.J. and M. Ingram. 2000. Drought in the context of the last 1000+ years: some surprising implications. In Drought: A Global Assessment, Vol 1, Ch 17:234-242. D. Wilhite, ed., Routledge Press, New York.

Abstract in Progress (71)

Hadly, E. A. . 1996. Influence of late-Holocene climate on northern Rocky Mountain mammals. Quaternary Research. 46 3: 298-310.

An exceptionally rich paleontological site containing thousands of mammalian fossils and well-dated with 18 radiocarbon samples provides evidence of late-Holocene ecological response to climatic change in northern Yellowstone National Park, Wyoming. The mammalian fauna, composed of 10,597 identified specimens, shows surprising affinity to the local habitat with little evidence of long-distance transport of faunal elements, thus revealing the faithfulness of a fossil site to the community from which it is derived. The mammals illustrate ecological sensitivity to a series of mesic to xeric climatic excursions in the sagebrush-grassland ecotone during the past 3200 yr. From 3200 cal yr B.P. to a maximum of 1100 cal yr B.P., the species composition of mammals indicates wetter conditions than today. Beginning about 1200 cal yr B.P., the fauna becomes more representative of xeric conditions with maxima in xeric-indicator taxa and minima in mesic-indicator taxa, concordant with the Medieval Warm Period (circa 1000 to 650 yr B.P.). Cooler, wetter conditions which prevailed for most of the Little Ice Age (700 to 100 yr B.P.) in general correspond to a return to a more mesic mammalian fauna. A warm period within the Little Ice Age is documented by a xeric fauna. These data show that mammalian ecological sensitivity to climatic change over this intermediate time scale holds promise for predictions about the impacts of future global warming. (Abstract by Hadly as printed in Quarternary Research). (72)

Hadly, E.A.. 1997. Evolutionary and ecological response of pocket gophers (Thomomys talpoides) to late-Holocene climatic change. Biological Journal of Linnean Society. 60:277-96.

Late-Holocene evolutionary and ecological response of pocket gophers and other species to climatic change is documented by fossils from Lamar Cave. Pocket gophers increase in abundance during mesic intervals and decline during xeric intervals. The same subspecies of pocket gopher (Thomomys talpoides tenellus) has occupied northern Yellowstone for at least 3200 years. (428)

Hall, M.H.P. and D.B. Fagre. 2001. Where Have All the Glaciers Gone? Modeling Climate-Induced Glacier Change in Glacier National Park, 1850 – 2100. BioScience (Accepted).

The glaciers in the Blackfoot–Jackson Glacier Basin of Glacier National Park, Montana, decreased in area from 21.6 square kilometers (km2) in 1850 to 7.4 km2 in 1979. Over this same period global temperatures increased by 0.45ºC (± 0.15ºC).We analyzed the climatic causes and ecological consequences of glacier retreat by creating spatially explicit models of the creation and ablation of glaciers and of the response of vegetation to climate change. We determined the melt rate and spatial distribution of glaciers under two possible future climate scenarios, one based on carbon dioxide–induced global warming and the other on a linear temperature extrapolation. Under the former scenario, all glaciers in the basin will disappear by the year 2030, despite predicted increases in precipitation; under the latter, melting is slower. Using a second model, we analyzed vegetation responses to variations in soil moisture and increasing temperature in a complex alpine landscape and predicted where plant communities are likely to be located as conditions change. (73)

Kilham, S. S., Theriot, E. C. , Fritz, S. C. . 1996. Linking planktonic diatoms and climate change in the large lakes of the Yellowstone ecosystem using resource theory. Limnology and Oceanography. 41 5: 1052-1062.

The 8 important planktonic diatom species in the large lakes of the Yellowstone region are ranked along resource ratio gradients according to their relative abilities to grow under limitation by Si, N, P, and light. Hypotheses based on resource physiology can be used to test the causal factors proposed to explain diatom distributions over the Holocene. (74)

Kittel, T.G.F. and J.A. Royle. 100-year climate history of the U.S. Rocky Mountains. J. Climate, in preparation.

Abstract in Progress (75)

Lyford, M.E., J.L. Betancourt, S.T. Jackson. 2002. Holocene vegetation and climate history of the northern Bighorn Basin, southern Montana. Quaternary Research. 58(2):171-181.

Records of Holocene vegetation and climate change at low elevations (<2000 m) are rare in the central Rocky Mountain region.We developed a record of Holocene vegetation and climate change from 55 14C-dated woodrat middens at two low-elevation sites (1275 to 1590 m), currently vegetated by Juniperus osteosperma woodlands, in the northern Bighorn Basin. Macrofossil and pollen analyses show that the early Holocene was cooler than today, with warming and drying in the middle Holocene. During the Holocene, boreal (Juniperus communis, J. horizontalis) and montane species (J. scopulorum) were replaced by a Great Basin species (J. osteosperma). J. osteosperma colonized the east side of the Pryor Mountains 4700 14C yr B.P. Downward movement of lower treeline indicates wetter conditions between 4400 and 2700 14C yr B.P. Increased aridity after 2700 14C yr B.P. initiated expansion of J. osteosperma from the east to west side of the Pryor Mountains. (Abstract by Lyford et al as printed in Quarternary Research). (76)

Millar, C.I., and W.B. Woolfenden. 1999. The role of climate change in interpreting historical variability. Ecological Applications 9:1207-1216.

Significant climate anomalies have characterized the last 1000 yr in the Sierra Nevada, California, USA. Two warm, dry periods of 150- and 200-yr duration occurred during AD 900-1350, which were followed by anomalously cold climates, known as the Little Ice Age, that lasted from AD 1400 to 1900. Climate in the last century has been significantly warmer. Regional biotic and physical response to these climatic periods occurred. Climate variability presents challenges when interpreting historical variability, including the need to accommodate climate effects when comparing current ecosystems to historical conditions, especially if comparisons are done to evaluate causes (e.g., human impacts) of differences, or to develop models for restoration of current ecosystems. Many historical studies focus on "presettlement" periods, which usually fall within the Little Ice Age. Thus, it should be assumed that ecosystems inferred for these historical periods responded to different climates than those at present, and management implications should be adjusted accordingly. The warmer centuries before the Little Ice Age may be a more appropriate analogue to the present, although no historic period is likely to be better as a model than an understanding of what conditions would be at present without intervention. Understanding the climate context of historical reconstruction studies, and adjusting implications to the present, should strengthen the value of historical variability research to management. (Abstract by Millar and Woolfenden as printed in Ecological Applications). (77)

Millspaugh, S. H. , Whitlock, C. , Bartlein, P. J. . 2000. Variations in fire frequency and climate over the last 17,000 years in central Yellowstone National Park. Geology. 28 3: 211-214. Yes- I have a copy

A 17 000 yr fire history from Yellowstone National Park demonstrates a strong link between changes in climate and variations in fire frequency on millennial time scales. The fire history reconstruction is based on a detailed charcoal stratigraphy from Cygnet Lake in the rhyolite plateau region. Macroscopic charcoal particles were tallied from contiguous 1 cm samples of a 6.69-m-long core, and the data were converted to charcoal-accumulation rates at evenly spaced time intervals. Intervals of high charcoal-accumulation rates were interpreted as local fire events on the basis of information obtained from modern charcoal-calibration studies in the Yellowstone region. The record indicates that fire frequency was moderate (4 fires/1000 yr) during the late glacial period, reached highest values in the early Holocene (>10 fires/1000 yr), and decreased after 7000 calendar yr B.P. The present fire regime (2-3 fires/1000 yr) was established in the past 2000 yr. The charcoal stratigraphy correlates well with variations in July insolation through time, which suggests that regional climate changes are responsible for the long-term variations in fire frequency. In the early Holocene, summer insolation was near its maximum, which resulted in warmer, effectively drier conditions throughout the northwestern United States. At this time, the fire frequency near Cygnet Lake was at its highest. After 7000 calendar yr B.P., summer insolation decreased to present values, the regional climate became cooler and wetter, and fires were less frequent. The Cygnet Lake record suggests that long-term fire frequencies have varied continuously with climate change, even when the vegetation has remained constant. (78)

Millspaugh, S.H. and Whitlock, C. in press. Postglacial fire, vegetation, and climate history of the Yellowstone-Lamar and Central Plateau provinces, Yellowstone National Park. In After the Fires: The Ecology of Change in Yellowstone National Park (L. Wallace, ed.). Yale University Press.

Abstract in Progress (79)

Romme, W. H. , Turner, M. G. . 1991. Implications of global climate change for biogeographic patterns on the Greater Yellowstone Ecosystem. Conservation Biology. 5 3: 373-386.

Projected changes in global climate have substantiated ramifications for biological diversity and the management of natural areas. We explored the potential implications of global climate change for biogeographic patterns in the Greater Yellowstone Ecosystem by using a conceptual model to compare three likely climate scenarios: 1) warmer and drier than the present; 2) warmer and drier, but with a compensating increase in plant water use efficiency; and 3) warmer and wetter than the present. The logical consequences of each scenario are projected for several species and community types chosen to represent a range of local climate conditions and biotic responses in the Greater Yellowstone Ecosystem. The upper and lower timberline appear to be particularly sensitive to climate change. The upper timberline is likely to migrate upward in elevation in response to temperature changes, whereas the lower treeline may retreat under drier conditions or move down slope under wetter conditions. In all scenarios, the extent of alpine vegetation in the ecosystem is decreased. Climate-induced changes in the fire regime in the Greater Yellowstone Ecosystem would probably have substantial consequences for the extent and age-class distribution of forest communities. Alterations in the distribution and extent of grassland communities would affect the populations of large ungulates. Our analyses suggest directions for establishing long-term measurements for the early detection of response to climate change. (81)

Stohlgren, T.J., T.N. Chase, R.A. Pielke, Sr., T.G.F. Kittel, and J. Baron. 1998. Evidence that local land use practices influence regional climate, vegetation, and stream flow patterns in adjacent natural areas. Global Change Biology 4:495-504. [ISI citation index = 23]

We present evidence that land use practices in the plains of Colorado influence regional climate and vegetation in adjacent natural areas in the Rocky Mountains in predictable ways. Mesoscale climate model simulations using the Colorado State University Regional Atmospheric Modelling System (RAMS) projected that modifications to natural vegetation in the plains, primarily due to agriculture and urbanization, could produce lower summer temperatures in the mountains. We corroborate the RAMS simulations with three independent sets of data: (i) climate records from 16 weather stations, which showed significant trends of decreasing July temperatures in recent decades; (ii) the distribution of seedlings of five dominant conifer species in Rocky Mountain National Park, Colorado, which suggested that cooler, wetter conditions occurred over roughly the same time period; and (iii) increased stream flow, normalized for changes in precipitation, during the summer months in four river basins, which also indicates cooler summer temperatures and lower transpiration at landscape scales. Combined, the mesoscale atmospheric/land-surface model, short-term trends in regional temperatures, forest distribution changes, and hydrology data indicate that the effects of land use practices on regional climate may overshadow larger-scale temperature changes commonly associated with observed increases in CO2 and other greenhouse gases.   (Abstract by Stohlgren et al as printed in Global Change Biology). (82)

Whitlock, C. . 1993. Postglacial vegetation and climate of Grand Teton and southern Yellowstone National Parks. Ecological Monographs. 63 2: 173-198.

Pollen records from northern Grand Teton National Park, the Pinyon Peak Highlands, and southern Yellowstone National Park were examined to study the pattern of reforestation and climatic change following late-Pinedale Glaciation. The vegetational reconstruction was aided by analyses of associated plant macrofossils and the modern pollen rain of the region. Radiocarbon-age determinations and tephrochronology provided a chronologic framework to help correlate pollen records among sites. The fossil records indicate that alpine meadow communities, with Betula and Juniperus, were present between ?14,000 and ?11,500 yr BP. This early assemblage implies a lowering of modern upper treeline by at least 600 m and a climate that was ?5-6 C colder than present. Between 11,500 and 10,500 yr BP, increased temperature and winter precipitation allowed first Picea, and then Abies and Pinus cf. albicaulis to spread into areas underlain by andesite and nonvolcanic bedrock. By 10,500 yr BP, the fossil record in these areas resembled modern spectra from subalpine forest. In contrast, the Central Plateau of Yellowstone, which is underlain by infertile rhyolitic soils, was treeless prior to ?10,000 yr BP. The absence of late-glacial subalpine parkland in this area is attributed to the same edaphic factors that limit Picea, Abies, and Pinus albicaulis from the rhyolite plateau today. Between 10,000 and 9,500 yr BP, Pinus contorta forest developed throughout the region in response to further warming. Pseudotsuga and Populus were present between 9,500 and 5,000 yr BP, suggesting a warmer, drier climate than today and more frequent fires. In the last 5,000 yr BP mixed forests of Picea, Pinus, and Abies have developed on andesitic and nonvolcanic terrain, and closed forests of Pinus contorta have persisted on rhyolitic substrates. The vegetational patterns are attributed to a combination of climatic and nonclimatic controls operating on different spatial and temporal scales. Climatic changes brought about by the retreat of Laurentide ice and the amplification of the seasonal cycle of radiation explain the broad patterns of vegetational change on millennial time scales. On shorter time scales and smaller spatial scales, substrate differences and migration history shaped the vegetational variability. (Abstract by Whitlock as printed in Ecological Monographs). (83)

Young, J.A., G.F. Vance and R. Zhang. 2000. Climatic patterns in the Bighorn Basin, Wyoming. Agricultural Experiment Station Bulletin, University of Wyoming, Laramie, WY. (In review)

Abstract in Progress (84)

ECOSYSTEM

Betancourt, Julio L. 1990. Chapter 12: Late Quaternary Biogeography of the Colorado Plateau. Pages 259-292 in Betancourt, Julio L., Van Devender, Thomas R., Martin, Paul S. Packrat Middens: The Last 40,000 Years of Biotic Change. University of Arizona Press, Tucson, AZ.

Extensive book with several references to Chaco Canyon (primarily in this chapter - see p. 262-265). Plant remains from these middens provide information about the plant species found at earlier time periods. Suggests there were stands of Pinus edulis and Juniperus monsperma available to the Anasazi and may have been wiped out by overuse or climatic change. (165)

Billings, W. D. 1994. Effects of global and regional environmental changes on mountain ecosystems. Pages 1-29 in Despain, D. G. . Plants and their Environments: proceedings of the First Biennial Scientific Conference on the Greater Yellowstone ecosystem, Sept 16-17, 1991, Mammoth Hot Springs Hotel. U. S. Department of the Interior, Natural Resources Publication Office, Denver, Colorado.

Abstract in Progress (85)

Christensen, J.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonia, R. Francis, J.F. Franklin, J.A. MacJahon, R.F. Noss, D.J. Parsons, CH. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. the report of the Ecological Society of America on the scientific basis for ecosystem management. Ecological Applicatoins 6(3):665-691.

Ecosystem management is not a rejection of an anthropocentric for a totally biocentric worldview. Rather it is management that acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet those needs in perpetuity has limits and depends on the functioning of ecosystems. (Abstract by Christensen et al. As published in Ecological Applications.) (167)

Coughenour, M.B. 1999. Ecosystem modeling of the Pryor Mountain Wild Horse Range. Report to USGS. Biological Resources Division, National Park Service, and Bureau of Land Management. 55pp + 100 Figs.

Abstract in Progress (87)

Debinski, D. M. , M. E. Jakubauskas, and K. Kindscher. 2000. Montane meadows as indicators of environmental change. Environmental Monitoring and Assessment. 64:213-225.

We used a time series of satellite multispectral imagery for mapping and monitoring six classes of montane meadows arrayed along a moisture gradient (from hydric to mesic to xeric).We hypothesized that mesic meadows would support the highest species diversity of plants, birds, and butterflies because they are more moderate environments. We also hypothesized that mesic meadows would exhibit the greatest seasonal and interannual variability in spectral response across years. Field sampling in each of the meadow types was conducted for plants, birds, and butterflies in 1997 and 1998. Mesic meadows supported the highest plant species diversity, but there was no significant difference in bird or butterfly species diversity among meadow types. These data show that it may be easier to detect significant differences in more species rich taxa (e.g., plants) than taxa that are represented by fewer species (e.g., butterflies and birds). Mesic meadows also showed the greatest seasonal and interannual variability in spectral response. Given the rich biodiversity of mesic montane meadows and their sensitivity to variations in temperature and moisture, they may be important to monitor in the context of environmental change. (Abstract by Debinski et al as printed in Environmental Monitoring and Assessment). (88)

Frank, D. A. , McNaughton, S. J. , Tracy, B. F. . 1998. The ecology of the earth's grazing ecosystems. Bioscience. 48 7: 513-521.

Studies of the Serengeti and Yellowstone ecosystems show many common properties. Yellowstone ungulates migrate seasonally, but for different environmental factors than Serengeti ungulates. The authors measured plant biomass concentration throughout the seasonal ranges of migrating animals. Just as eliminating processes such as fire that occur at large spatial scales, so eliminating migrating grazers by fragmenting grazing ecosystems alters the fundamental character of the habitat. (89)

Frank, D.A., and S.J. McNaughton. 1992. the ecology of plants, large mammalian herbivores, and drought in Yellowstone National Park. Ecology. 73(6):2043-2058.

The purpose of this study was to examine the effect of abundant native large herbivores on ecosystem function of a spatially and temporally heterogeneous temperate grassland. Net aboveground primary production (ANPP), large herbivore consumption (C), and dung deposition (D), an index of nutrient flow from herbivores to the soil, were measured in grassland and shrub-grassland habitat on winter, transitional, and summer range used by herds of elk (Cervus elaphus) and bison (Bison bison) in northern Yellowstone National Park. Temporary exclosures (5-7 per site) were moved every 4 wk during the snow-free season to determine ANPP and C. Data were collected during 1988, a year of drought and unusually high elk and bison population levels, and 1989, a climatically near-average year, with dramatically fewer elk and bison. All three processes, ANPP, C, and D, varied widely among sites: ANPP range: 16-589 g/m super(2), C range: 0-306 g/m super(2), and D range: 0-68 g/m super(2). An average of 45% of ANPP was consumed by herbivores. Production and consumption, and consumption and dung deposition were positively correlated across all sites. In addition, sites were grazed when plants were growing. There was 19% reduction in ANPP from 1988 to 1989, likely caused by death or injury to plants during the 1988 drought. Drought also appeared to be partially responsible for reductions in elk and bison from 1988 to 1989, which were coincident with declines in C and D. Results indicate direct effects and suggest indirect effects of a single-season drought on grassland function that will persist for several years after the event. (90)

Greenlee, J. ed. 1996. The ecological implications of fire in Greater Yellowstone: Second biennial conference on the Greater Yllowstone Ecosystem. International Assoc. of Wildland Fire, Fairfield, Washington.

Thirty-three papers from the conference (91)

Holling, C.S. (1992). Cross-scale morphology, geometry, and dynamics of ecosystems. Ecol. Monogr., 62(4): 447-502.

This paper tests the proposition that a small set of plant, animal, and abiotic processes structure ecosystems across scales in time and space. Earlier studies have suggested that these key structuring processes establish a small number of dominant temporal frequencies that entrain other processes. These frequencies often differ from each other by at least an order of magnitude. If true, ecosystems therefore will have a few dominant frequencies that are endogenously driven and that are discontinuously distributed. This paper additionally tests the proposition that these structuring processes should also generate a discontinuous distribution of spatial structures coupled with the discontinuous frequencies. If that is the case, animals living in specific landscapes should demonstrate the existence of this lumpy architecture by showing gaps in the distribution of their sizes. This proved to be the case for birds and mammals of the boreal region forest and the short-grass prairie. Alternative hypotheses to explain the body mass clumps include architectural, developmental, historical, and trophic causes. These were all tested by comparing body-mass clump distributions (1) in ecosystems having different spatial structures (forest, grassland, and marine pelagic) and (2) in different animal groups having different body plans (birds and mammals) or feeding habits (carnivore, omnivore, and herbivore). The only hypothesis that could not be rejected in that the body-mass clumps are entrained by discontinuous hierarchical structures and textures of the landscape. There is evidence for at least eight distinct habitat "quanta," each defined by a distinct texture at a specific range of scales. These eight quanta together cover tens of centimeters to hundreds of kilometers in space and at least months to millennia in time.
There is a striking similarity, but not identity, between the clump structure of prairie and boreal animals. This indicates that many processes that form qualitative habitat structure are common to both landscapes or ecosystems, but a few are landscape specific, particularly over larger scales. That conclusion is extended to all terrestrial ecosystems by an analysis of the body-mass clump structure of all North American birds.
In contrast, there are striking differences in clump structure between landscapes and "waterscapes," indicating that fundamentally different processes shape structure in terrestrial and open ocean systems. The discontinuous body-mass structure provides a bioassay of discontinuous ecosystem structure. Mammalian carnivores, omnivores, and herbivores all show the same number of body-mass clumps, and the gaps in these distributions occur at the same body masses. Mammals and birds show the same number of body-mass clumps, but the mass gaps for mammals occur at larger sizes than those for birds in such a way that the log-transformed body mass gaps for mammals are correlated linearly with those for birds. Hence there is a simple cross-calibration between the mammal and bird bioassays. I compiled and analyzed published data on home ranges in order to convert body masses into an absolute linear

measure of geometric structures in the landscape. A new and general equation was developed relating home-range size to body mass, and was tested by reanalyzing published data for mammalian carnivores, omnivores and herbivores and for birds. I conclude: (1) Birds and mammals of all trophic levels utilize resources in their foraging areas in the same way by measuring the spatial grain of habitat patches with a resolution defined as a function of their size (i.e., the animal's step length or minimum unit of measurement). The step length is a morphological function of the size of animals and is not significantly affected by trophic status or taxonomy of the groups considered. That explains why all trophic levels and both birds and mammals show the same qualitative body-mass clump structure. (2) Home-range data can convert the body-mass data to a quantitative estimate of texture, i.e., of fractal dimension of the landscape. The landscape forms a hierarchy that contains breaks in object sizes, object proximities, and textures at particular scales. Animals also demonstrate a hierarchy of decisions whose target suddenly shifts at specific scales in space and time. The interaction between these two hierarchies produces the discontinuous body-mass clump structure. The breaks in geometry in the landscape occur because structuring processes exert their influence over defined ranges of scale. The temporal and architectural structure of habitat quanta are in general determined by three classes of processes, each dominating over three different ranges of scale. Vegetative processes that determine plant growth, plant form, and soil structure dominate the formation of texture at fine microscales of centimetres to tens of metres in space and days to decades in time. At the other, macroscale extreme, slow geomorphological processes dominate the formation of a topographic and edaphic structure at large scales of hundreds to thousands of kilometres and centuries to millennia. At the mesoscales in between, contagious disturbance processes such as fire, insect outbreak, plant disease, and water flow dominate the formation of patterns over spatial scales of hundreds of metres to hundreds of kilometres. In addition, the direct impacts of grazing by large herbivores and of human activities, and the indirect effects of large predators and animal disease, further transform spatial patterns over these meso-scales. These processes operate on time scales of years to decades, making them critically important in determining whether present local, regional, and global human influences will trigger a transition in vegetation types, and, if so, how rapidly. The paper provides a direction for the development of programs to evaluate, monitor, and predict ecosystem and community changes across scales. The necessary research elements include (1) models that incorporate a few scale-dependent structuring processes to allow cross-scale analysis; (2) comparative studies of different disturbed and undisturbed landscapes using the animal body-mass bioassay technique to identify critical scales of ecosystem geometry; (3) analysis of remote imagery to identify spatial discontinuities and regions of scale invariance; and (4) behavioral studies of the hierarchy of animal decisions to identify species groups vulnerable to predicted (using models) or observed (using remote imagery) changes in vegetation geometry. (92)

Huff, D. E. , Varley, J. D. . 1999. Natural regulation in Yellowstone National Park's northern range. Ecological Applications. 9 1: 17-29.

"...It is the opinion of the authors that extensive published data support the position that current elk populations and sympatric herbivores do not exceed the ecological carrying capacity of the northern range: therefore, the range is not overgrazed by ecological standards..." (93)

Huntley, N. J. , Sirotnak, J. M. . 1998. The role of small mammals in the Greater Yellowstone ecosystem. Pages 37 in No Editor/Author. Making a place for nature, seeking our place in nature: 125th Anniversary Symposium, May 11-23, 1998; agenda and abstracts. Yellowstone Association, Yellowstone National Park.

The Greater Yellowstone Ecosystem harbors populations of many small mammals. Despite their small individual size, these animals can be locally abundant, and research shows that they can play important, though frequently overlooked, roles in ecosystem dynamics. For instance, voles (Microtus species) can change the patterns of nitrogen mineralization in riparian areas, which have been shown to have plant communities that are nitrogen-limited. Voles' effects are particularly interesting in that they change over the course of the population cycle that is typical of these small herbivores. The change through time in nitrogen mineralization is accompanied by, and we speculate is caused by, changes in the plant community that appear to result from voles' activities. The net outcome is the fluctuation of plant species abundance and nitrogen availability over a several year time-scale. Another small mammal that is common at high elevations in the Greater Yellowstone region is the pika (Ochotona princeps), a lagomorph. Pikas have been shown to alter vegetation in subalpine areas. Recent work on the Beartooth Plateau shows that they sometimes similarly alter the vegetation of high alpine areas. Additionally, they appear to cause development of spatially variable soils. Pocket gophers (Geomyidae) also are common in many meadow-types of the Greater Yellowstone Ecosystem. Work in Yellowstone Park and nearby regions shows that these animals frequently play an important role in generating heterogeneity in soil quality and behavior, and, through this, can change the productivity and species composition of plant communities. In addition to their direct effects on soils and plant, small mammals are an important link of the food webs that characterize montane and higher elevation areas of the Greater Yellowstone region, providing a significant food source for many carnivores. Although our studies are limited to distribution of small mammals and their effects on plant communities and soil dynamics, we also review literature that suggests the interactions of the small mammal community with the larger fauna of the park and the ways in which fire may influence the abundance, distribution, and ecological effects of small mammals. (Abstract by Huntley and Sirotnak. As printed in Making a place for nature, seeking our place in nature: 125th Anniversary Symposium, May 11-23, 1998; agenda and abstracts.) (94)

Kay, C.E. 1998. Are ecosystems structured from the top-down or bottom-up: a new look at an old debate. Wildlife Society Bulletin. 26 3:484-498.

"Native Americans were the ultimate keystone predator...until the importance of aboriginal land management is recognized and modern management practices change accordingly, our ecosystems will continue to lose the biological diversity and ecological integrity they once had..." (95)

Keiter, R. B. , Boyce, M. S. 1991. The Greater Yellowstone ecosystem: redefining America's wilderness heritage. Yale University Press, New Haven.

Abstract in Progress (96)

Landres, P.B., P. Morgan, and F.J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9: 1179-1188.

Natural resource managers have used natural variability concepts since the early 1960 s and are increasingly relying on these concepts to maintain biological diversity, to restore ecosystems that have been severely altered, and as benchmarks for assessing anthropogenic change. &. We conclude that natural variability concepts provide a framework for improved understanding of ecological systems and the changes occurring in these systems, as well as for evaluating the consequences of proposed management actions. &. These concepts can also be misused. &. Natural variability concepts offer an opportunity and a challenge for ecologists to provide relevant information and to collaborate with managers to improve the management of ecological systems (97)

LaRoe, E. T., G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. 1995. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service

Abstract in Progress (98)

Leopold, A. S., S. A. Cain, C. M. Cottam, I. N. Gabrielson, and T. L. Kimball. 1963. Wildlife management in the national parks. Transactions of North American Wildlife and Natural Resources Conference 28:28-45.

This report emphasizes biological principles involved, defines the aesthetic, historical and scientific values of the parks, and sets forth the philosophy of management thus called for. (99)

Marshall, Kent G., Knight, Dennis H., Barmore, William J. , Jr. 1979. An indexed and annotated bibliography on the ecology of Grand Teton National Park : including unpublished literature. University of Wyoming, National Park Service Research Center, Laramie, WY.

Contains citation concerning the ecology of Grand Teton National Park (100)

Meagher, M.M., and D.B. Houston. 1998. Yellowstone and Biology of Time: Photographs Across a Cantury. Norman: University of Oklahoma Press.

Consists of an extensive series of pictures comparing various sites taken at 2 or 3 widely separated dates, with cogent explanations of possible reasons for differences in growth patterns and their implications. (101)

National Research Council. 2002. Ecological Dynamics on Yellowstone's Northern Range. National Academy Press, Washington, D.C. 144 pages.

Abstract in Progress (663)

Ojima, D.S., T.G.F. Kittel, T. Rosswall, and B.H. Walker. 1991. Critical issues for understanding global change effects on terrestrial ecosystems. Ecological Applications 1:316-325. [ISI citation index = 29]

Marked alterations in the Earth's environment have already been observed, and these presage even greater changes as the impact of human (i.e., land use and industrial) activities increases. Direct and indirect feedbacks link terrestrial ecosystems with global change, and include interactions affecting fluxes of water, energy, nutrients, and "greenhouse" gases and affecting ecosystem structure and composition. Community development can affect ecosystem dynamics by altering resource partitioning among biotic components and through changes in structural characteristics, thereby affecting feedbacks to global change. The response of

terrestrial ecosystems to the climate-weather system is dependent on the spatial scale of the interactions between these systems and the temporal scale that links the various components. The International Geosphere-Biosphere Programme (IGBP), which was initiated by the International Council of Scientific Unions (ICSU) in 1986, has undertaken to develop a research plan to address a predictive understanding of how terrestrial ecosystems will be impacted by global changes in the environment and the potential feedbacks. The IGBP science plan, which incorporates established Core Projects and activities related to research on terrestrial ecosystem linkages to global change, includes the International Global Atmospheric Chemistry Project (IGAC); the Biospheric Aspects of the Hydrological Cycle (BAHC); the Global Change and Terrestrial Ecosystems (GCTE); Global Analysis, Integration, and Modelling (GAIM); IGBP Data and Information System (DIS); and IGBP Regional Research Centers (RRC). The coupling of research and policy communities for the purpose of developing mechanisms to adapt to these impending changes urgently needs to be established. (Abstract by Ojima et al. As published in Ecological Applications.) (102)

Parson, D.J., R.W. Swetnam, and N.L. Christensen. 1999. Uses and limitations of historical variability concepts in manageing ecosystems. Ecological Applications 9:4 p.1177-1178

"Despite the wide diversity of approaches and opinions regarding the best ways to utilize historical data, it is clear that there is great value in considering historical-ecological information in natural resource planning and management. Although the application of such information may vary widely, depending on the quality and resolution of the available data and the goals and constraints of those applying the information, the value of historical perspectives in understanding factors influencing the structure and function of ecological systems is critical to almost all resource management decisions. We hope, and expect, that the discussion generated by these papers will stimulate increased dialogue between scientists and managers regarding the value and limitations of historical variability data in developing scientifically based land management programs." (103)

Schullery, P. 1995. The greater Yellowstone ecosystem. Pages 312-314 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Park Service

Status summary for the Greater Yellowstone ecosystem, the "last large, nearly intact ecosystem in the northern temperate zone of the earth," and the controversies over management. (104)

Sinclair, A. R. E. 1998. Natural regulation of ecosystems in protected areas as ecological baselines. Wildlife Society Bulletin. 26 3: 399-409.

Ecological baseline areas are necessary benchmarks to detect slow change and predict fast change in ecosystems that humans depend upon. National parks, by default, fulfill this role provided they are large enough to maintain natural processes. They should be used to understand natural regulatory ecosystem processes that are then compared with other human-dominated systems. Natural regulation operates through negative feedback mechanisms in reproduction or mortality caused by factors such as food shortage and predation. Protected areas are capable of self-regulation as evidenced by many studies of such ecosystems covering several decades. They exhibit natural change, often with periodicities of decades or centuries, and such change must be accommodated in management plans. Ecosystems exhibit >1 natural state, often as a result of top-down processes such as predation and herbivory. These multistates are identified by their irreversibility when the cause of perturbations is removed. They are characterized by >1 combination of population densities and species. Predators may or may not be present, and herbivores may or may not impinge on the vegetation. Therefore, there is no single combination of species or ecosystem stated for which management should strive. Naturalness, per se, is not the objective. Rather, the fundamental need is to compare ecosystems experiencing modern human impact with those in protected areas that are relatively free of such impacts so as to understand their consequences for mankind. The presence or absence of prehistoric humans is not relevant to these objectives. Management, however, should act to minimize disturbance, such as the presence of exotic species, within these ecological baselines. Monitoring of ecosystem change should be coordinated on a global basis, using simple and robust techniques. (Abstract by Sinclair as printed in Wildlife Society Bulletin). (105)

Whitlock, C., Reasoner, M.A., and Key, C.H. 2002. Paleoenviromental History of the Rocky Mountain region during the last 20,000 years. In Rocky Mountain Futures: An Ecological Perspective (J.A. Barron, ed) Ch 3: 41-59. Island Press.

Ecosystem management is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function. In recent years, sustainability has become an explicitly stated, even legislatively mandated, goal of natural resource management agencies. In practice, however, management approaches have often focused on maximizing short-term yield and economic gain rather than long-term sustainability. Several obstacles contribute to this disparity, including: (1) inadequate information on the biological diversity of environments; (2) widespread ignorance of the function and dynamics of ecosystems; (3) the openness and interconnectedness of ecosystems on scales that transcend management boundaries; (4) a prevailing public perception that the immediate economic and social value of supposedly renewable resources outweighs the risk of future ecosystems damage or the benefits of alternative management approaches. The goal of ecosystem management is to overcome these obstacles. Ecosystem management includes the following element: (1) Sustainability. Ecosystem management does not focus primarily on "deliverables" but rather regards intergenerational sustainability as a precondition. (2) Goal. Ecosystems management establishes measurable goals that specify future processes and outcomes necessary for sustainability. (3) Sound ecological models and understanding. Ecosystem management relies on research performed at all levels of ecological organization. (4) Complexity and connectedness. Ecosystem management recognizes that biological diversity and structural complexity strengthen ecosystems against disturbance and supply the genetic resources necessary to adapt to long-term change. (5) The dynamic character of ecosystems. Recognizing that change and evolution are inherent in ecosystem sustainability, ecosystem management avoids attempts to "freeze" ecosystems in a particular state or configuration. (6) Context and scale. Ecosystem processes operate over a wide range of spatial and temporal scales, and their behavior at any given location is greatly affected by surrounding systems. Thus, there is no single appropriate scale or time frame for management. (7) Humans as ecosystem components. Ecosystem management values the active role of humans in achieving sustainable management goals. (8) Adaptability and accountability. Ecosystem management acknowledges that current knowledge and paradigms of ecosystem function are provisional, incomplete, and subject to change. Management approaches must be viewed as hypotheses to be tested by research and monitoring programs. The following are fundamental scientific precepts for ecosystem management. (1) Spatial and temporal scale are critical. Ecosystem function includes inputs, outputs, cycling of materials and energy, and the interactions of organisms. Boundaries defined for the study or management of one process are often inappropriate for the study of others; thus, ecosystem management requires a broad view. (2) Ecosystem function depends on its structure, diversity, and integrity. Ecosystem management seeks to maintain biological diversity as a critical component in strengthening ecosystems against disturbance. Thus, management of biological diversity requires a broad perspective and recognition that the complexity and function of any particular location is influenced heavily by the surrounding system. (3) Ecosystem are dynamic in space and time. Ecosystem management is challenging in part because ecosystems are constantly changing. Over time scales of decades or centuries, many landscapes are altered by natural disturbances that lead to mosaics of successional patches of different ages. Such patches dynamics are critical to ecosystem structure and function. (4) Uncertainty, surprise, and limits to knowledge. Ecosystem management acknowledges that, given sufficient time and space, unlikely events are certain to occur. Adaptive management addresses this uncertainty by combining democratic principles, scientific analysis, education, and institutional learning to increase our understanding of ecosystem processes and the consequences of management interventions, and to improve the quality of data upon which decisions must be made. Ecosystem management requires applications of ecological science to natural resource actions. Moving from concepts to practice is a daunting challenge and will require the following steps and actions. (1) Defining sustainable goals and objectives. Sustainable strategies for the provision of ecosystem goods and services cannot take as their starting points statements of need or want such as mandated timber supply, water demand, or arbitrarily set harvest of shrimp or fish. Rather, sustainability must be the primary objective, and levels of commodity and amenity provision must be adjusted to meet that goal. (2) Reconciling spatial scales. Implementation of ecosystem management would be greatly simplified if management jurisdictions were spatially congruent with the behavior of ecosystem processes. Given the variation in spatial domain among processes, one perfect fit for all processes is virtually impossible; rather, ecosystem management must seek consensus among the various stakeholders within each ecosystem. (3) Reconciling temporal scales. Whereas management agencies are often forced to make decisions on a fiscal-year basis, ecosystem management must deal with time scales that transcend human lifetimes. Ecosystem management requires long-term planning and commitment. (4) Making the system adaptable and accountable. Successful ecosystem management requires institutions that are adaptable to changes in ecosystem characteristics and in our knowledge base. Adaptive management by definition requires the scientist's ongoing interaction with managers and the public. Communication must flow in both directions, and scientists must be willing to prioritize their research with regard to critical management needs. Scientists have much to offer in the development of monitoring programs, particularly in creating sampling approaches, statistical analyses, and scientific models. As our knowledge base evolves, scientists must develop new mechanisms to communicate research and management results. More professionals with an understanding of scientific, management, and social tissues, and the ability to communicate with scientists, managers, and the public are needed. Ecosystem management is not a rejection of an anthropocentric for a totally biocentric worldview. Rather it is management that acknowledges the importance of human needs while at the same time confronting the reality that the capacity of

our world to meet those needs in perpetuity has limits and depends on the functioning of ecosystems. (Abstract by Christensen et al. As published in Ecological Applications.) (166)

Yellowstone National Park. 1997. Yellowstone's Northern Range: complexity and change in a wild-land ecosystem. National Park Service, Mammoth Hot Springs, Wyoming.
Abstract in Progress (662)

Macdonald, I.A.E., L.L. Loope, M.B. Usher, and O. Hamann. 1989. Wildlife conservation and the invasion of nature reserves by alien species: a global perspective, p. 215-255. In J.A. Drake and others (eds.), Ecology of Biological Invasions: a Global Synthesis. John Wiley & Sons, Chichester, U.K.
Discusses the ways in which introduced species can affect nature conservation. Describes current invasions and provides examples, successes and failures, of management of these invasions. Section on island ecosystems. (108)

EXOTIC

Olliff, T. ,et. al. 2001. Managing a Complex Exotic Vegetation Program in Yellowstone National Park. Western North American Naturalist. 61 3: 347-358.
The number of documented exotic plants in Yellowstone National Park has increased from 85 known in 1986 to over 185 today. Exotic plants are substantially impacting the park's natural and cultural resources and are a high management priority. We have adopted an integrated weed management approach with regard to exotic vegetation, emphasizing prevention, education, early detection and eradication, control, and, to a lesser degree, monitoring. The program involves over 140 staff with program expenditures averaging approximately $190,000 annually. Prevention actions include requiring approved gravel on construction projects; banning hay in the backcountry and allowing transport of only certified weed-seed-free hay through Yellowstone; requiring construction equipment to be pressure-cleaned prior to entering the park; and native species revegetation after road, housing, and other construction projects have disturbed ground. Over 4500 acres, primarily along roadsides and in developed areas, are surveyed annually in early detection efforts with emphasis placed on eradicating small, new infestations of highly invasive species such as sulfur cinquefoil (Potentilla recta L.) and leafy spurge (Euohirbia esula L.) Control efforts focus on about 30 priority species, such as spotted knapweed (Centaurea maculosa Lam.), oxeye daisy (Chrysanthemum leucanthemum L.), and hoary cress (Cardaria draba [L.] Desv.) using chemical, mechanical, and cultural techniques. A total of 2027 acres were treated during 1998, whereas control efforts for 12 species occurred on 2596 acres during the precious 3-year period, 1995-1997. Strong and expanding partnerships with other federal, state, and local agencies and private companies contribute to management efforts within the park. Future program goals emphasize increases in base funding to ensure continued weed management efforts as well as expanding survey, monitoring, and reclamation efforts. Ultimately, a more rigorous assessment of program effectiveness is desired. (Abstract by Olliff et al as printed in Western North American Naturalist). (303)

Vitousek, P.M., C.M. D'Antonio, L.L. Loope, and R. Westbrooks. 1996. Biological invasions as global environmental change. American Scientist 84:468-478.

Argues that biological invasions have become so wide-spread that they constitute a significant component of global environmental change. Challenges two beliefs that help perpetuate this cycle: the idea that invasions are a natural process that has always been a part of evolutionary history; and the assumption that the ease of travel and the continued expansion of the global economy will make it impossible to prevent invasions. Identifies a need for improvements to legal frameworks that concern the control of exotic species; and suggests a need for greater public awareness of (and involvement in) this problem. (109)

FIRE

Bessie, W.C., and E.A. Johnson. 1995. the relative importance of fuels and weather on fire behavior in subalpine forests. Ecology 76: 747-762.

Surface fire intensity (kilowatts per metre) and crown fire initiation were predicted using Rothermel's 1972 and Van Wagner's 1977 fire models with fuel data from 47 upland subalpine conifer stands varying in age from 22-258 yr and 35 yr of daily weather data (fuel moisture and wind speeds). Rothermel's intensity model was divided into a fuel component variable and weather component variable, which were then used to examine the relative roles of fuel and weather on surface fire intensity (kilowatts per metre). Similar variables were defined in the crown fire initiation were strongly related to the weather components and weakly related to the fuel components, due to much greater variability in weather than for fuel, and stronger relationship to the fire behavior mechanisms for weather than for fuel. Fire intensity was correlated to annual area burned; large area burned years had higher fire intensity predictions than smaller area burned years. The reason for this difference was attributed directly to the weather variable frequency distribution, which was shifted towards more extreme values in years in which large areas burned. During extreme weather conditions, the relative importance of fuels diminishes since all stands achieve the threshold required to permit crown fire development. This is important since most of the area burned in subalpine forests has historically occurred during very extreme weather (i.e., drought coupled to high winds). The fire behavior relationships predicted in the models support the concept that forest fire behavior is determined primarily by weather variation among years rather than fuel variation associated with stand age. (Abstract by Bessie and Johnson. As printed in Ecology) (110)

Boyce, M. S. , Merrill, E. H. . 1996. Predicting effects of 1988 fires on ungulates in Yellowstone National Park. Pages 361-368 in Singer, F. J. . Effects of grazing by wild ungulates in Yellowstone National Park. National Park Service, Natural Resource Information Division, Denver

We used computer simulation to forecast the effects of the 1988 fires on bison (Bos bison) and elk (Cervus elaphus) in Yellowstone National Park, based on our studies of these two species before the fires. Few ungulates died as a direct result of the 1988 fires in Yellowstone National Park. The greatest effects of the fires are expected to be changes in the forage base for these animals. Most of the area burned was summer range. Only 9% of the grasslands normally used by elk and bison on the northern range during winter burned. Before the 1988 fires, factors were studied that influenced population dynamics of elk and bison in Yellowstone. Three variables—summer herbaceous biomass, winter severity, and population size—accounted for most of the year-to-year variance in per capita population growth rates for both species. These three parameters were modeled into a stochastic difference equation for each species. According to the model, the population for both elk and bison at the beginning of winter 1988-89 was larger than average carrying capacity due to a series of mild winters. High overwinter mortality during spring 1989 was therefore largely a consequence of abnormally high populations and slightly more severe winter weather. According to other studies, drought during the summer of 1988 and the burned winter ranges further aggravated the situation. Vegetation succession was used to project consequences of the 1988 fires to elk and bison populations. Both elk and bison should have enhanced recruitment and population size for several years, gradually declining to long-term carrying capacities of approximately 3,000 bison and 20,000 elk overwintering in the park. (Abstract by Boyce and Merrill as printed in Effects of grazing by wild ungulates in Yellowstone National Park). (111)

Knight, D. H. , Wallace, L. L.. 1989. The Yellowstone fires: issues in landscape ecology. Bioscience. 39 10: 700-706.

Addresses fire-caused temporal and spatial variability in vegetation patterns, plant-animal relationships, and land-water interactions in Yellowstone National Park. (112)

Loope, L. L., and G. E. Gruell. 1973. The ecological role of fire in Jackson Hole, northwestern Wyoming. Quaternary Research 3:425-443.

Fire-history investigations in the Jackson Hole area of northwestern Wyoming reveal that most current stands of aspen and lodgepole pine regenerated following extensive fires between 1840 and 1890 and that widespread fires occurred in the 1600s and the 1700s. White man's major effect on the fire incidence has been the successful suppression during the past 30-80 yr. Successional changes in the absence of fire include the deterioration of aspen stands, massive invasions of subalpine fir in lodgepole pine stands, great increase in conifer cover, heavy fuel buildup in lodgepole pine and Douglas fir stands, and increase in sagebrush and other shrubs. Steps are being taken, starting in 1972, to allow fire to play a more natural role in Grand Teton and Yellowstone National Parks. Teton National Forest plans experimental prescribed burning to determine wheteer fire can stimulate successful aspen regeneration in the prescense of large numbers of wintering elk. (Abstract by Loope as printed in Quaternary Research). (113)

Meyer, G.A., Wells, S.G. and A.J.T. Jull. 1995. Fire and alluvial chronology in Yellowstone National Park: climatic and intrinsic controls on Holocene geomorphic processes. Geological Society of America Bulletin 107: 1211-1230.

Debris-flow and flood events following the 1988 fires provided facies models for interpreting the stratigraphic record of fire-related sedimentation within valley-side alluvial fans of Soda Butte Creek. .. Fire-related deposits make up ca. 30% of the late Holocene fan alluvium... A major pulse of fire-related debris-flow activity between 950 and 800 B.P. coincided with the Medieval Warm Period...Instrumental climate records over the last ~100yr in Yellowstone imply that the intensity and interannual variability of summer precipitation are greater during warmer periods, enhancing the potential for severe short-term drought, major forest fires, and storm-generated fan deposition. (114)

Romme, W. H. , Despain, D. G. . 1989. Historical perspective on the Yellowstone fires of 1988. Bioscience. 39 10: 695-699.

In this article, the authors compare the fires of 1988 with fires during the previous 350 years. The authors use both information contained in park files and results of our tree-ring research on the prehistoric fire history. (115)

Schullery, P. , Despain, D. G. . 1989. Prescribed burning in Yellowstone National Park: a doubtful proposition. 1989. Wildlands 15(2):30-34.

The fires of 1988 raised many questions about the use of human-set prescribed burns in Yellowstone. It has been proposed that an aggressive program of prescribed burns was either ecologically necessary before the fires, or could have prevented the fires from growing as large as they did. These suggestions are interesting, and should be addressed, even if to some extent such conjectural exercises may be inconclusive. Most of all, such suggestions lead to some fascinating insights into the ecological and philosophical challenges of managing large natural areas such as Yellowstone Park. (116)

Turner, M. G. , Romme, W. H. , Gardner, R. H. , Hargrove, W. W. . 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. Ecological Monographs. 67 4: 411-433.

Study analyzed whether vegetation responses differed between small and large burned patches within the fire-created mosaic and evaluated the influence of spatial patterning on postfire vegetation. (117)

Turner, M. G. , Romme, W. H. . 1994. Landscape dynamics in crown fire ecosystems. Landscape Ecology. 9: 59-77.

Crown fires create broad-scale patterns in vegetation by producing a patch mosaic of stand age classes, but the spread and behavior of crown fires also may be constrained by spatial patterns in terrain and fuels across the landscape. In this review, we address the implications of landscape heterogeneity for crown fire behavior and the ecological effects of crown fires over large areas. We suggest that fine-scale mechanisms of fire spread can be extrapolated to make broad-scale predictions of landscape pattern by coupling the knowledge obtained from mechanistic and empirical fire behavior models with spatially-explicit probabilistic models of fire spread. Climatic conditions exert a dominant control over crown fire behavior and spread, but topographic and physiographic features in the landscape and the spatial arrangement and types of fuels have a strong influence on fire spread, especially when burning conditions (e.g. fuel moisture and wind) are not extreme. General trends in crown fire regimes and stand age class distributions can be observed across continental, latitudinal, and elevational gradients. Crown fires are more frequent in regions having more frequent and/or severe droughts, and younger stands tend to dominate these landscapes. Landscapes dominated by crown fires appear to be nonequilibrium systems. This nonequilibrium condition presents a significant challenge to land managers, particularly when the implications of potential changes in the global climate are considered. Potential changes in the global climate may alter not only the frequency of crown fires but also their severity. Crown fires rarely consume the entire forest, and the spatial heterogeneity of burn severity patterns creates a wide range of local effects and is likely to influence plant reestablishment as well as many other ecological processes. Increased knowledge of ecological processes at regional scales and the effects of landscape pattern on fire dynamics should provide insight into our understanding of the behavior and consequences of crown fires. (Abstract by Turner and Romme and printed in Landscape Ecology). (186)

Bozek, M. A., Young, M. K. . 1994. Fish mortality resulting from delayed effects of fire in the greater Yellowstone ecosystem. Great Basin Naturalist. 54 1: 91-95.

Often public concern focuses on the immediate, terrestrial impacts of wildfire. Such was the case during the summer and fall of 1988 when fires burned 562,000 ha in the Greater Yellowstone Ecosystem (Greater Yellowstone Ecosystem). Besides the obvious loss of vegetation, less apparent, short-term consequences of these fires to terrestrial ecosystems included greater nutrient availability, widespread soil modification, and direct and indirect mortality of wildlife. But as a result of the linkages between streams and their valleys, fires also may affect the hydrology, water chemistry, and geomorphology of aquatic ecosystems. During the 1988 in the Greater Yellowstone Ecosystem, Minshall et al. observed fish kills in streams, but the extent and causes of mortality were not reported. While conducting other studies of watersheds in the Greater Yellowstone Ecosystem, we observed a fish kill in a burned watershed that occurred two years after the fires. In this paper we describe aspects of this fish kill and relate them to hydrologic conditions in this stream and those in a nearby stream with an unburned watershed. (471)

FISH

Gresswell, R. E. , Liss, W. J. 1995. Values associated with management of Yellowstone Cutthroat trout in Yellowstone National Park. Conservation Biology. 9 1: 159-165.

Recent emphasis on a holistic view of natural systems and their management is associated with a growing appreciation of the role of human values in these systems. In the past, resource management has been perceived as a dichotomy between extraction (harvest) and nonconsumptive use, but this appears to be an oversimplified view of natural-cultural systems. The recreational fishery for Yellowstone cutthroat trout (Oncorhynchus clarki bouvieri) in Yellowstone National Park is an example of the effects of management on a natural-cultural system Although angler harvest has been drastically reduced or prohibited the recreational value of Yellowstone cutthroat trout estimated by angling factors (such as landing rate or size) ranks above that of all other sport species in Yellowstone National Park. To maintain an indigenous fishery resource of this quality with hatchery propagation is not economically or technically feasible. Nonconsumptive uses of the Yellowstone cutthroat trout including fish-watching and intangible values, such as existence demand, provide additional support for protection of wild Yellowstone cutthroat trout populations. A management strategy that reduces resource extraction has provided a means to sustain a quality recreational fishery while enhancing values associated with the protection of natural systems. (118)

Gresswell, R. E. , Liss, W. J., Larson, G. L. , Bartlein, P. J. . 1997. Influence of basin-scale physical variables on life-history characteristics of cutthroat trout in Yellowstone Lake. North American Journal of Fisheries Management. 17: 1046-1064.

Examines basin-scale physical characteristics of tributary drainages and subbasins of Yellowstone Lake in relation to timing (peak and duration) of lacustrine-adfluvial Yellowstone cutthroat trout spawning migrations and mean length of cutthroat trout spawners in 27 tributaries to the lake; found evidence of distinct aggregations of cutthroat trout that are related to physical and limnological characteristics of the lake subbasins. (119)

Knapp, R.A., P.S. Corn, and D.E. Schindler. 2001. The introduction of nonnative fish into wilderness lakes: good intentions, conflicting mandates, and unintended consequences. Ecosystems 4: 275–278.

Abstract in Progress (120)

Schullery, P. , Varley, J. D. . 1994. Fires and fish: the fate of Yellowstone waters since 1988. Trout. V. 35 p. 16-23.

Six years after the 1988 Yellowstone fires, the authors examine research results of the influence of fire on watersheds and relate that to fish health. The '88 fires effected over 100,000 acres in every major watershed in Yellowstone National Park without any major fish kills recorded. The influence of a fire on a watershed is a factor of many pre-fire conditions (i.e. slope, aspect, type of vegetation burned, elevation) and post-fire conditions (namely precipitation patterns). Changes in groundwater chemistry occurred, but not outside the norms. Foreseen species change of aquatic invertebrates was documented and will continue, but is not expected to endanger fish populations. The authors conclude with a discussion on the impact of the fires on park management including a brief history of fish management in the park. (121)

Varley, J.D.. and P. Shullery. 1998. Yellowstone fishes: Ecology, history, and angling in the park. Stackpole Books, Mechanicsburg, Penn. 154 pp.

Abstract in Progress (122)

FOREST

Allen, K.K. and J.L. Harris. 1999. Insects and diseases of the Bighorn National Forest. Internal report, Bighorn National Forest, Sheridan, Wyoming.

Abstract in Progress (123)

Anderson, Peter George. 1994. Conifer Forest Dynamics in Grand Teton National Park, Wyoming. University of Utah, Salt Lake City, UT.

The objective of this study is to determine past and present conifer forest patterns and processes, and to project future forest mosaics of the valley conifer forest in Grand Teton National Park, Wyoming. The hypothesis that the present forest mosaic of Grand Teton National Park has not been adversely affected by twentieth century forest fire suppression is examined. The forested moraine of the Bradley - Taggart Lakes area provides a case study of forest pattern and process. Historical aspects of vegetation development in Jackson Hole and Grand Teton National Park are discussed. Plant assemblages and the forest mosaic are analyzed using phytosociological methods. Forest community dynamics and historic tree distributions and growth influences are evaluated using dendroecological methods. Information derived from these methodologies forms the database for a landscape scale, vegetation simulation model. The model is utilized to simulate forest dynamics and project future forest mosaics. Vital attributes theory and forest composition, structure, and diversity are used to evaluate the successional pathways of the forest mosaics. I suggest that twentieth century forest fire suppression has not altered successional dynamics and pathways of the forest mosaic of Grand Teton National Park. However, if forest fire suppression is reinstituted, I suggest that successional dynamics will precede along multiple pathways that will alter the forest mosaic, changing energy, nutrient, and water cycles and balances, impacting the biotic habitat of the Grand Teton National Park - Jackson Hole area ecosystem. (124)

Arct, M. J. , Chadwick, A. V. . 1983. Dendrochronology in the Yellowstone fossil forest. Abstracts with Programs - Geological Society of America. 15 5: 408.

The ability to crossdate trees implies that they were sensitive to some aspect of their environment- usually temperature or precipitation. Since procedures used in traditional dendrochronology are impractical when dealing with fossil assemblages with this method. The interpretation of growth features is based on modern analogues.

Thin sections of ring sequences were prepared from 37 coniferous stumps and logs from a 12 m thick section located near the base of the bands, false rings, bark rings, and climatic cycles (ring widths). Nine upright stumps (~40 years old) including pine, spruce and Douglas fir, sampled 1-3 m above their associated "soils" contained a series of 5 rings, 25-21 years before the final ring which displayed highly correlatable intra-annual bands corresponding to temporarily infavorable growth conditions. Ring 9 typically was small with a late season increase in water availability that caused a false ring feature in many trees. Although rings 8-4 were consistently large, bark rings show that several trees ceased growing in ring 4 while others indicated an instantaneous death before the end of the growing season in ring 1. Crumpled tracheids and insect galleries suggest a severe infestation was in progress to account for the early death of some trees.

Five older trees (~120 years) agree with the basic growth pattern of the younger trees. A period of reduced growth, probably related to drought and insect damage, occurs near ring 40. Subsequent rapid growth occurs coincident with the origin of younger trees.

Crossdated petrified trees thus promise a wealth of new paleoenvironmental information for the deposits in which they occur. (Abstract by Arct et al as printed in Agronomy Abstracts). (125)

Fahey, T.J. and D.H. Knight. 1986. Lodgepole pine ecosystems. BioScience 36:610-617.

The authors studied structurally contrasting stands of lodgepole pine in the Medicine Bow Mountains of Wyoming. Investigating the effect of water and nutrient flux in this relatively cool and dry ecosystem, they discussed related hydrology, low nitrogen content, and ion flow. These characteristics were found to contribute to biota and overall structure and function of the ecosystem. A consideration of the factors investigated is thought by the authors to be pertinent to management issues, although they suggest a more complete understanding is needed. They research the relatively simple lodgepole pine ecosystem in detail as an insight to the increasing complexity within which other forest types operate. (126)

Foster, D.R., D.H. Knight, and J.F. Franklin. 1998. Landscape patterns and legacies resulting from large infrequent forest disturbances. Ecosystems 1(6): 497-510.

Includes 1988 fires in a discussion of effects of large, infrequent disturbance. Resulting landscape patterns are strongly controlled by interactions between the specific disturbance, the abiotic environment, and the composition and structure of the vegetation at the time of disturbance. (127)

Hawksworth, F.G. and D.W. Johnson. 1989. Biology and management of dwarf mistletoe in lodgepole pine in the Rocky Mountains. USDA Forest Service General Technical Report RM-169.

This publication synthesizes the vast literature on lodgepole pine dwarf mistletoe (Arceuthobium americanum) and adds some new information on biology of the parasite. Although dwarf mistletoe has been recognized as a serious parasite of lodgepole pine for more than 75 years, its routine operational control through forest management has been primarily a development over the past two decades. This report discussed silvicultural control of dwarf mistletoe in various types of stands where fiber production is the primary goal, and also in forests used mainly for recreation. (Abstract by Hawksworth and Johnson as printed in General Technical Report RM-169). (128)

Kendall, K.C. and R.E. Keane. 2001. Whitebark pine decline: Infection, mortality, and population trends. Pages 221-242 in Tomback, D.F., S.F. Arno, and R.E. Keane (eds.). Whitebark pine communities: Ecology and restoration. Island Press. Washington, DC. (Book Chapter)

The authors examine whitebark pine decline mechanisms including: white pine blister rust, mountain pine beetle and dwarf mistletoe, and fire exclusion. They also look at the temporal scale of decline and regional population trends. They conclude with a look at the future in whitebark pine communities. (129)

Knight, D.H. 1994. Dynamics of subalpine forests. Pages 128-138 in G.D. Hayward and J. Verner, editors. Flammulated, boreal, and great gray owls in the United States: a technical conservation assessment. USDA Forest Service General Technical Report RM-253

The boreal owl's fairly specific habitat requirements restrict its range in the conterminous U.S. to subalpine forests (see Chapter 9). These forests provide tree cavities, incrusted snow that facilitates preying on small mammals, and cool microclimates essential for summer roosting. Such forests also provide habitat for the owl's prey, which consists primarily of red-backed voles, mice, and other small mammals. Significantly, these prey animals often eat lichens and the sporocarps of fungi. Both are common at high elevations or along drainages in the middle and northern Rocky Mountains, the Blue Mountains, and the northern Cascade Range. This chapter focuses on the distribution, structure, and dynamics of subalpine forests in these areas, with emphasis on the Rocky Mountains. (Abstract by Knight as printed in General Technical Report RM-253). (131)

Loope, Lloyd L. 1971. Dynamics of forest communities in Grand Teton National Park. Naturalist. 22 1: 39-47.

Loope describes the ecology of the seven major tree types in Grand Teton National Park: lodgepole pine, whitebark pine, limber pine, Englemann spruce, subalpine fir, Douglas fir, and aspen. He proposed that the present (1971) forest composition and extent of species is due to a number of interactions between the tree species and climate, soils, and other living organisms. He describes in depth the ecology of the seven main species types in Grand Teton National Park including distribution, susceptibility to fire and disease, reproductive traits and age characteristics. He also examines the historical role of fire in the Teton Range, in the valley bottoms, and on the Yellowstone plateau and relates the effects these fires have had on the current forest composition and extent. Fire dates were determined from tree-ring record of fire scars and historical accounts. The impact of these fires is also explored in terms of forest health, namely, species susceptibility to disease. Loope concludes with a list of six consequences of continued fire exclusion in Grand Teton National Park and a recommendation for more research on fire suppression and primitive forest conditions. (132)

Lundquist, J.E. 1993. Large scale spatial patterns of conifer diseases in the Bighorn Mountains, Wyoming. Research Note RM-523. USDA forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

A roadside reconnaissance for forest diseases in the Bighorn National Forest was conducted in 1991. The most common disorders were dwarf mistletoe, Comandra blister rust, western gall rust, and an undetermined needlecast of lodgepole pine; broom rusts, patch mortality, branch canker, and crown mortality of Engelmann spruce and subalpine fir; and white pine blister rust of limber pine. The most widespread disorders showed the creates diversity across the forest. Two or more disorders (average=4) occurred concurrently on all townships. (Abstract by Lundquist as printed in Research Note RM-523). (133)

Lynch, E.A. 1998. Origin of a park-forest vegetation mosaic in the Wind River Range, Wyoming. Ecology. 79(4):1320-1338.

Abstract in Progress (134)

Mattson, D.J., K.C. Kendall, D.P. Reinhart. 2001. Whitebark pine, grizzly bears, and red squirrels. In: Whitebark pine communities, ecology and restoration. Eds. D. Tomback, S.F. Arno, and R.E. Keane. Island Press, Washington DC.

Abstract in Progress (135)

McMillin, J.D. and K.K. Allen. 2000. Impacts of Douglas-fir beetle on overstory and understory conditions of Douglas-fir stands, Shoshone National Forest, Wyoming. USDA Forest Service Technical Report R2-64, Golden, Colorado.

Douglas-fir beetle (Dendroctonus pseudotsugae) infestations frequently result from disturbance events that create large volumes of weakened Douglas-fir (Pseudotsuga menziesii) trees. Although research has focused on measuring and predicting the amount of tree mortality caused by Douglas-fir beetle infestations following disturbance events, there has been an inadequate amount of work on the consequent changes in both the overstory and understory. In 1988, extensive wildfires occurred in Yellowstone National Park and the Shoshone National Forest. Populations of Douglas-fir beetle increased in firescorched trees caused by the wildfires. Subsequent generations of the beetles moved from these injured trees to undamaged trees in neighboring stands on the Shoshone National Forest, Wyoming. In 1999, Forest Health Management personnel quantified changes in forest stand conditions and subsequent responses in the understory caused by the Douglas-fir beetle infestation using transect sampling (20 miles) and 25 pairs of previously infested and uninfested plots. Significant effects of the Douglas-fir beetle infestation included: 1) Basal area was reduced by 40 - 70 percent, tree diameter decreased by 8 - 40 percent, and the Douglas-fir component of the overstory decreased by more than 15 percent. 2) Conifer seedling regeneration increased nearly four-fold in the infested plots and 90 percent of the regeneration was Douglas-fir. 3) The understory vegetation (forbs, grass, and shrubs) had a three-fold increase in the infested plots compared with uninfested plots. In addition, basal area of Douglas-fir killed by the Douglas-fir beetle was significantly correlated with initial Douglas-fir basal area and percent of Douglas-fir, but not tree diameter or trees per hectare. Significant inverse relationships were also found

between post-infestation basal area and the abundance of forbs, grass, shrubs, and understory height. Based on these results, Douglas-fir beetle infestations, although causing significant shortterm impacts in both the overstory and understory, probably are not changing the long-term successional patterns. Management alternatives are presented to control Douglas-fir beetle impacts for areas where the beetle is jeopardizing forest objectives. Information gathered from this study will be useful to the Shoshone National Forest, and other national forests both inside and outside the region, and the Yellowstone National Park. (136)

Merrill, E., J. Hak, and S. Beauchaine. 1993. Forest fragmentation and bird diversity in the Bighorn National Forest, Wyoming. EMAP-01-93, Project #R-82-1748. Report on file at the Wyoming Game and Fish Department, Sheridan, WY.

Abstract in Progress (137)

Meyer, C.B., and D.H. Knight. In review. Historic range of variability of upland vegetation in the Bighorn National Forest, Wyoming. U.S. Forest Service Report.

Abstract in Progress (138)

Miller, C. and D. L. Urban. 1999. Interactions between forest heterogeneity and surface fire regimes in the southern Sierra Nevada. Canadian Journal of Forest Research 29: 202-212.

Fire is a major agent of spatial pattern formation in forests, as it creates a mosaic of burned and unburned patches. While most research has focused on landscape-level patterns created by crown fires, millions of hectares of forests in North America are subject to surface fire regimes. A spatially explicit forest gap model developed for the Sierra Nevada was used to evaluate the influence of surface fire regimes on the heterogeneity of forest structure and composition within forest stands. Forest pattern was evaluated for a wide range of topographic position in Sequoia National Park. The spatial heterogeneity of some forest characteristics increased under a simulated fire regime relative to scenarios without fire. &. The interaction between surface fires and forest pattern may be qualitatively different from that which occurs in forests subject to crown fires. As such, what has been learned about forests dominated by crown fires may not apply to forests subject to surface fire regimes (139)

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10: 58-62.

Edges are presumed to have deleterious consequences for the organisms that remain in forest fragments. However, there is substantial discrepancy among recent studies about the existence and intensity of edge effects. Most studies have focused on seeking simplistic and static patterns. Very few have tested mechanistic hypotheses or explored the factors that modulate edge effects. Consequently, studies are very site-specific and their results cannot be generalized to produce a universal theory of edges. Although estimates of the intensity and impact of edge effects in fragmented forests are urgently required, little can be done to ameliorate edge effects unless their mechanics are better understood. (Abstract by Murcia as printed in TREE). (140)

Patten, D. T. . 1969. Forest succession in Yellowstone National Park. National Parks Magazine. 43 264: 21-22.

lodgepole pine forests in Yellowstone and forest succession. (141)

Renkin, R.A., and D.G. Despain. 1992. Fuel moisture, forest type and lightning-caused fire in Yellowstone National Park. Can. J. for. Res. 22(1)37-45.

The occurrence and behavior of lightning-caused fires in Yellowstone National Park were summarized for 17 years (1972-1988) during a prescribed natural fire program. Both ignition (occurrence) and spread (stand replacing fire activity) of fires were strongly influenced by fuel moisture and forest cover type. Fuel moisture estimates of 13% for large (gt 7.6 cm) dead and downed fuels indicated a threshold below which proportionately more fire starts and increased stand replacing fire activity were observed. During periods of suitable fuel moisture conditions, fire occurrence and activity were significantly greater than expected in old-growth, mixed-canopy lodgepole pine (Pinus contorta Dougl. var. latifolia) and Englemann spruce-subalpine fir (Picea engelmannii Parry-Abies lasiocarpa (Hook.) Nutt.) forest types, and significantly less than expected in the successional lodgepole pine forest types. During periods of extended low fuel moisture conditions (drought), sustained high winds significantly reduced the influence of forest cover type on stand replacing fire activity. These extreme weather conditions were observed during the later stages of the 1988 fire season, and to a lesser extent, for a short duration during the 1981 fire season. The Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) forest type typically supported little stand replacing fire activity, even though a preponderance of fire starts was observed. (142)

Rochefort, R.M., et al. (1994). Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors. The Holocene, 4(1): 89-100.

Changes in the distribution of sub-alpine tree species in western North America have been attributed to climatic change and other environmental stresses. These changes include tree-line fluctuations throughout the Holocene and recent invasion of subalpine meadows by forest. Most paleoecological studies suggest that the tree-line was higher during a period of warmer climate advance. Recent advances in sub-alpine tree distribution can be compared with weather records, allowing and examination of relationships between tree advance and climate at a finer resolution. In general, recent sub-alpine forest advances in western North America, based on studies representing three climatic zones (maritime, Mediterranean and continental), have been associated with climatic periods favoring tree germination and growth, although factors such as fire and razing by domestic livestock have had an impact in some area. Limitations to tree establishment (e.g., winter snow accumulation, summer drought) vary in relative importance within each climate zone, as do predicted consequences of anthropogenic climate change. Recent increased in establishment of sub-alpine trees may continue if climatic change alleviates the limitations to tree establishment important in each climatic zone. However, factors such as topography and disturbance may modify tree establishment on a local scale. (Abstract by Rochefort et al as printed in The Holocene). (143)

Romme, W. H., and D. H. Knight. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62:319-326.

Differences in fire frequency and the rate of secondary succession following fire have had a major effect on the present composition of forest vegetation in a 4500-ha undisturbed watershed in the subalpine zone of the Medicine Bow Mountains, southeastern Wyoming, USA. Periodic fire coupled with slow secondary succession has perpetuated lodgepole pine forest on the upland, while mature Engelmann spruce-subalpine fir forest have developed in sheltered ravines and valley bottoms where fire is less frequent and succession following fire is more rapid and/or more direct. A graphic model is presented showing the relationship between topographic position, fire-free interval, and the occurrence of mature forests dominated by spruce and fir. (Abstract by Romme and Knight as printed in Ecology). (144)

Schmidt, W. C. , McDonald, K. J. . Proceedings - Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High Mountain Resource. Intermountain Research Station, US Department of Agriculture Forest Service, Ogden, UT.

Abstract in Progress (313)

Vance, G.F. and D.H. Knight. 1999. Coarse woody debris and soil organic matter in Rocky Mountain coniferous forests. Agronomy Abstracts, 91:365

Natural and human disturbances to forest ecosystems can alter above-and below-ground C pools that influence vegetation and soil energy and nutrient flows, wildlife habitats, and sequestration potentials. Large quantities of course woody debris (CWD) are produced by natural disturbances (e.g., fires, insect outbreaks, wind storms) whereas timber harvest (e.g., bolewood, whole tree) removes much of the CWD. The objectives of this study were to: 1) compare the volume and distribution of CWD that remains following disturbances and 2) evaluate the quality and quantity of soil organic matter (OM) under CWD and forest litter layers. For objective 1, CWD was measured in clearcut/uncut stands in the Medicine Bow Mountains and in burned/unburned stands in Yellowstone National Park. Results indicated a net loss (80 Mg/ha of >7.5 cm dia.) of CWD in clearcut stands and an average gain (95 Mg.ha) in stands that burn. Objective 2 results suggested soil OM under CWD sites was higher in N and 65% greater in phenolic products. Soil solutions from CWD sites were more acidic, had higher N, P, and S nutrients and greater percentages of acid DOC fractions. (Abstract by Vance and Knight as printed in Agronomy Abstracts). (145)

GEOLOGY

Antweiler, J.C., J.D. Love, H.J. Prostka, D.M.. Kulik, L.A. Anderson, F.e. Williams, J.E. Jinks, and T.D.. Light. 1989. Mineral resources of the Teton Wilderness and adjacent areas, Teton, Fremont, and Park counties, Wyoming: U.S. Geol. Surv. Bulletin 1781

Discusses a mineral survey of the Teton Wilderness and adjacent areas (146)

Baker, R.G. . 1986. Sangamonian and Wisconsin paleoenvironments in Yellowstone National Park: Geol. Soc. America Bulletin, vol. 97, p. 717-736, 13 figs, 1 table.

Pollen and plant macrofossil records from Yellowstone National Park, if combined with dated glacial events, provide a paleoenvironmental record of much of the last glacial-interglacial cycle. Bull Lake glaciation has been dated at ~140,000 yr B.P. Section EP-6 records a late-glacial to full interglacial sequence which is correlated with the Sangamonian interglacial and estimated to be 127,000 yr old at the peak warm period. A prevailing Pseudotsuga-Pinus flexilis-Pinus ponderosa forest suggests that climate was considerably warmer than any in the Holocene. Section EP-5 is somewhat younger, probably late Sangamonian, and shows forest dominated by Picea, Abies, Pseudotsuga, and a haploxylon Pinus. Slightly cooler conditions than those of the present are indicated. The warmest phase of Grassy Lake Reservoir section is considered to be ~82,000 yr old and records a warm interstadial cycle beginning with tundra.

The warming sequence is indicated by change to a Picea-Abies-Pinus albicaulis forest and then to a Pinus contorta forest. The cycle ends with forest destruction and a return to open (tundra?) and, presumably, cold conditions. Extremely low values of arboreal pollen indicate that tundra vegetation and cold conditions continued from ~70,000 to ~50,000 yr B.P. One cool and, apparently, short interstadial interrupted this extended period of tundra shortly after 68,000 B.P. when a very open parkland of Picea-Abies-Pinus albicaulis appeared. No records of environment are available between ~50,000 and 30,000 yr B.P. The Pinedale icecap apparently expanded ~30,000 yr B.P. and lasted until ~14,000 yr B.P. Late-glacial Picea-Abies-Pinus albicaulis parklands gave way to Pinus contorta forests that have prevailed with minor variation for ~10,000 yr. (Abstract by Baker as printed in Geological Society of America Bulletin). (147)

Barnosky, A. D. . 1998. A long term view of the Greater Yellowstone geoecosystem. Pages 26 in No Editor/Author. Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts. Yellowstone Association, Yellowstone

Geology influences ecosystem structure and function at a variety of temporal and spatial scales, ranging from millions of years on a continental scale to tens of years on a local scale. The present ecosystem in and around Yellowstone Park therefore reflects a composite of interactions between geological and biological processes that have been ongoing since the northern Rocky Mountains first uplifted. This composite results from processes that take place on million-year scales (e.g., tectonism and long-term volcanic patterns), hundred-thousand year scales (e.g., long-term climate trends), ten-thousand to several hundred year scales (specific climate changes and volcanic events), and the decadal scale (e.g., weather-driven events, geologically-influenced human settlement patterns). Data from intermontane basins in and around the Greater Yellowstone area indicate that the geological processes included (1) widespread volcanism during the Eocene, and global circulation patterns that resulted in tropical to subtropical environments; (2) a period of regional uplift, block-faulting, and erosion during the Miocene that defined major aspects of the regional topography and was accompanied by global climate change that resulted in locally arid environments; (3) local volcanism during the Miocene; (4) late Miocene/early Pliocene uplift in and around Yellowstone Park, which regionally increased precipitation gradients and opened previously tectonically dammed valleys; (5) Pliocene and Pleistocene volcanism and overprinting of topographic and geophysical relationships related to the approach of the Yellowstone hotspot; (6) Pleistocene glaciation related to global cooling; and (7) retreat of glaciers during the Holocene, related to global warming. The overprints of these geological events on the modern biota include: (1) a pattern of biodiversity that relates to the fragmentation of the northern Rocky Mountain region into the basins and ranges; (2) a legacy of constituent taxa determined by evolutionary constraints, proximity of immigrants, and chance opening and closing of dispersal corridors; and (3) the activities of humans related to utilizing, recreating, and living in an area they are attracted to in part because of the geological setting. (Abstract by Barnosky. As printed in Making a place for nature, seeking our place in nature: 125th Anniversary Symposium, May 11-23, 1998; agenda and abstracts.) (148)

Christiansen, R. L. . 1998. Geology of Yellowstone National Park and vicinity as the foundation of the Yellowstone geoecosystem. Pages 30 in No Editor/Author. Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts

The unique character of the Yellowstone geoecosystem reflects a complex geologic evolution. Farther north much of the Continental Divide is a sharp mountainous backbone; through parts of Wyoming it is topographically inconspicuous. By contrast, a great plateau spans the Divide in Yellowstone at nearly 2500 m elevation. The specific trace of the Divide across this plateau is less significant than the broad high expanse at the headwaters of two great drainage systems. The Yellowstone Plateau is built upon mountains raised during the Laramide orogeny between about 70 and 55 million years (m.y.) ago. Before then, sedimentary rocks had been laid down over about 500 m.y. in a variety of environments, mainly but not entirely marine, upon a substructure of ancient crystalline rocks (~2600 m.y.). During the Laramide the continental crust was folded and thrust-faulted into numerous mountain ranges and intervening broad sedimentary basins. Postorogenic volcanism partly coalesced from northwestern Wyoming to the Pacific Coast. Much of the Rocky Mountain region still reflects a pattern inherited from the Laramide orogeny and early post-Laramide volcanism, as in the Gallatin, Snowy, and Absaroka Ranges of the Yellowstone region. Superimposed on the Laramide framework are younger basins and ranges formed by tectonic extension, mainly in the Great Basin region to the southwest but also in high ranges and adjacent valleys from central Idaho to northwestern Wyoming, dating mainly from the past 10 m.y. Slicing across these younger ranges, is the eastern Snake River Plain, the track of voluminous magmatism that, during the same time, propagated from southwest to northeast. Both extensional basin-range deformation and magmatism continue, as in the Teton Range and Jackson Hole and the Yellowstone Plateau volcanism of the past 2 m.y. Yellowstone Plateau volcanism differed significantly from that of many other areas. Rather then lofty stratocones or bulky volcanic shields, enormous volumes of rhyolitic magma erupted, partly as lavas but largely as explosively ejected pumice and volcanic ash that not only dispersed widely through the atmosphere but swept the landscape in searing density flows. Coming to rest, these hot ash flows welded to form broad lava-like sheets of rhyolite over thousands of square kilometers. The larges eruptions were three massive events 2.0, 1.3, and 0.6 m.y. ago, each ejecting hundreds to thousands of cubic kilometers of magma in a few hours or days, withdrawing crustal support to cause large areas to founder into gigantic craterlike calderas, subsequently filled with lavas and sediments to form the plateau. The outcrop pattern and the specific character of Yellowstone's rocks, especially the volcanic rocks and surficial deposits of streams, lakes, glaciers, and rock falls derived from them, determine much of the vegetation pattern of the plateau and its surrounding ranges. Heat from the still active magmatic system sustains Yellowstone's geysers, hot springs, and fumaroles, upon which the mega faunal population relies during winters, when they are often isolated from former grazing and hunting ranges. (Abstract by Christiansen, R. L.. As printed in Making a place for nature, seeking our place in nature: 125th Anniversary Symposium, May 11-23, 1998; agenda and abstracts.) (149)

Dorf, Erling, "The Petrified Forests of Yellowstone Park," Scientific American, 210 (4), 106 (April 1964).

Summary of the Yellowstone petrified forests and fossil plants. (150)

Doser, D.I. and R.B. Smith (1983). Seismicity of the Teton-Southern Yellowstone region: Bull. Seism. Soc. Am., vol. 73, p. 1369-1394, 12 figs, 3 tables.

Epicenter patterns, focal depths, and focal mechanisms for earthquakes occurring between 1973 and 1981 in the Teton-Jackson Hole-southern Yellowstone region are presented.

Earthquake information recorded prior to 1980 was combined with two microearthquake surveys operated in 1980 and 1981. The majority of earthquakes do not appear to be associated with mapped traces of Quaternary faults. The Teton Fault appears active at the small earthquake level along some segments, although several segments appear to be quiescent. Seismicity in the Gros Ventre Range may be related to reactivation of older basement structures. Fault plane solutions show predominately normal faulting with extension in an east-west to northwest-southeast direction. Geologic seismic moment rates of 1.1 X 10(24) dyne-cm/yr for the Teton region and 4.0 X 10(23) dyne-cm/yr for the Teton Fault were estimated using available geologic information on mapped faults. From the limited available data, a return period of 130 to 155 yr for a magnitude 6.5 to 7.5 earthquake is predicted for the Teton region, while the Teton Fault has a predicted return period of 8000 to 1800 yr for a magnitude 7.5 earthquake. A regional strain rate of 6.9 X 10(-9)/yr is also obtained.--Modified journal abstract. (151)

Kharaka, Y.K. and A.S. Maest, eds. 1992. Proc. Of the 7th intern. Symp. On water-rock interaction-WRI-7. Park City, UT.

Abstract in Progress (152)

Love, J.D., J.C. Reed, and K.L. Pierce. 2001. Creation of the Teton Landscape, A geologic chronicle of Jackson Hole and The Teton Range. A 156-page manuscript plus 96 illustrations was completed in early 2001 and submitted to the Grand Teton National History Association for evaluation for publication.

Abstract in Progress (153)

Pierce, K.L. 1979. History and dynamics of glaciation in the Northern Yellowstone National Park Area. U.S. Geological Survey Professional Paper 729-F.

Yellowstone National Park, the oldest of the areas set aside as part of the national park system, lies amidst the Rocky Mountains in northwestern Wyoming and adjacent parts of Montana and Idaho. Embracing large, diverse, and complex geologic features, the park is in an area that is critical to the interpretation of many significant regional geologic problems. In order to provide basic data bearing on these problems, the U.S. Geological Survey in 1965 initiated a broad program of comprehensive geologic and geophysical investigations within the park. This program was carried out with the cooperation of the National Park Service, and was also aided by the National Aeronautics and Space Administration, which supported the gathering of geologic information needed in testing and in interpreting results from various remote sensing devices. This professional paper chapter is one of a series of technical geologic reports resulting from these investigations. (154)

Pierce, K.L. and L.A. Morgan. 1990. The track of the Yellowstone Hotspot: volcanism, faulting, and uplift: U.S. Geol Surv. Open File Rept 90-415, 68 pp., 24 gis, 3 tables.

The track of the Yellowstone hotspot is represented by a systematic NE-trending linear belt of silicic, caldera-forming volcanism that arrived at Yellowstone 2 Ma, was near American Falls, Idaho, about 10 Ma, and started about 16 Ma near the Nevada-Oregon-Idaho border. From 10-2 Ma, silicic volcanism migrated N 54 E towards Yellowstone at about 3 cm/yr, leaving in its wake the eastern Snake River Plain (SRP). The eastern SRP is a linear, mountain-bounded, 75-km-wide trench almost entirely floored by calderas that are thinly covered by basalt flows. From 16-10 Ma, particularly 16-14 Ma, volcanism was widely dispersed around the interred hotspot track in a region that now forms a moderately high volcanic plateau. The current hotspot position at Yellowstone is spatially related to active faulting and uplift. Basin-and-range faults in the Yellowstone-SRP region are classified into six types based on both recency of offset and height of the associated bedrock escarpment. The distribution of these fault types permits definition of three adjoining belts and a pattern of waxing, culminating, and waning activity. The central belt, Belt II, is the most active and is characterized by faults active since 15 ka on range fronts >700 m high. Belt II has two arms forming a "V" that joins at Yellowstone: one arm of Belt II trends south to the Wasatch front; the other arm trends west and includes the sites of the 1959 Hebgen Lake and 1983 Borah Peak earthquakes. Fault Belt I is farthest away from the SRP and contains relatively new and reactivated faults that have not produced new bedrock escarpments higher than 200 m during the present episode of faulting. Belt III is the innermost active belt near the SRP. It contains faults that have moved since 15-120 ka and which have been active long enough to produce range fronts more than 500 m high. A belt with inactive faults occurs only south of the SRP and contains late Tertiary range-front faults that experienced high rates of activity coincident with hotspot volcanism on the adjacent SRP. Comparison of activity based on these belts with that defined by modern seismicity is remarkably similar but differs in detail. Uplift migrating outward from the hotspot track is suggested by (1) the Yellowstone crescent of high terrain that is about 0.5 km higher than the surrounding terrain, is about 350 km across at Yellowstone, wraps around Yellowstone like a bow wave, and has arms that extend 400 km southerly and westerly from its apex, (2) readily erodible rocks forming young, high mountains in parts of this crescent, (3) geodetic surveys and paleotopographic reconstructions that indicate young uplift near the axis of the Yellowstone crescent, (4) on the outer slope of this crescent, glaciers during the last glaciation were anomalously long compared with those of the preceding glaciation, suggesting uplift during the intervening interglaciation, and (5) lateral migration of steams, apparent tilting of stream terraces away from Yellowstone, and , from increasingly younger terrace pairs, migration away from Yellowstone of their divergent-convergent inflection point. We conclude that the neotectonic fault belts and the Yellowstone crescent of high terrain reflect heating that has migrated to distances as much as 200 km from the eastern SRP in 10 m.y, and that the only mechanism for such heat transport is flow of hot material within the asthenosphere, most likely by a thermal mantle plume rising to the base of the lithosphere and flowing outward horizontally for at least such distances. The change in the volcanic track between 16-10 Ma and 10-2 Ma is readily explained by first the head (300 km diameter) and then the chimney (10-20 km across) phases of a thermal mantle plume rising to the base of the SW-moving North American plate. About 16 Ma, the bulbous plume head intercepted and mushroomed out at the base of the lithosphere, resulting in widespread magmatism and tectonism centered near the common borders of Nevada, Oregon, and Idaho. Starting about 10 Ma near American Falls and progressing to Yellowstone, the chimney penetrated through its less active head and spread outward at the base of the lithosphere, adding basaltic magma and heat to the overriding SW-moving lithospheric plate, and leaving in its "wake" the eastern-SRP-Yellowstone track of calderas, and forming, ahead and outward from this track, the outward-moving belts of active faulting and uplift. We favor a mantle plume explanation for the hotspot track and associated tectonism and find problems with competing hypotheses that include the following: (1) for a rift origin, faulting and extension directions are at nearly right angles to that appropriate for a rift, (2) for a transform origin, geologic evidence requires neither a crustal flaw nor differential extension across the eastern SRP, and volcanic alignments on the SRP do not indicate a right-lateral shear across the SRP. The southern Oregon rhyolite zone is not analogous to the eastern SRP and therefore does not disprove formation of the Yellowstone hotspot track by a mantle plume. The postulated rise of a mantle-plume head into the mantle lithosphere about 16 Ma corresponds in both time and space with the following geologic changes: (1) the start of the present pattern of basin-range extension, (2) intrusion of basalt and rhyolite along the 1,100-km-long Nevada-Oregon rift zone, (3) the main phases of flood basalt volcanism of the Columbia River and Oregon plateaus, and (4) a change from calc-alkaline volcanism of intermediate to silicic composition to basaltic and bimodal rhyolite/basalt volcanism. (Abstract by Pierce and Morgan. As printed in U.S. Geol Surv. Open File Rept 90-415.) (155)

Richards, P.W. 1955. Geology of the Bighorn Canyon-Hardin Area, Montana and Wyoming. US Geological Survey Bulletin 1026

This report describes the geology of an area of about 1,300 square miles in south-central Montana extending from Hardin, Mont., southward across part of the Great Plains to the Bighorn Mountains and thence southwestward through the mountains along Bighorn Canyon to the Bighorn Basin. The area is mostly within the Crow Indian Reservation in southwestern Big Horn County, Mont., but it includes parts of Carbon County, Mont., and Big Horn County, Wyo., and less than 10 square miles of the southeast part of Yellowstone County, Mont. The only incorporated town within the area is Hardin, the county seat of Big Horn County, Mont., and the only other settlement is St. Xavier, Mont. The region is drained by the Bighorn River and its tributaries. The main valleys are cultivated. The proposed Yellowtail dam, in the canyon of the Bighorn River near the east edge of the Bighorn Mountains, would create a reservoir 70 miles long and provide irrigation water for extensive terrace lands along the Bighorn River. About 9,000 feet of sedimentary rocks, ranging in age from Cambrian to Late Cretaceous, are exposed in the area. Pre-Cambrian granites and metamorphic rocks, which form the central parts of the Bighorn Mountains and are separated from the overlying sedimentary rocks by an erosional unconformity, do not crop out in the area. In the deepest part of Bighorn Canyon approximately the upper 700 feet of about 1,000 feet of shale and thin-bedded limestone that make up the Cambrian Gros Ventre formation and Gallatin limestone is exposed. Resistant limestone and dolomite which overlie the Gallatin comprise 400 feet of Bighorn dolomite of Ordovician age, 200 feet of undivided Jefferson limestone and Three Forks shale of Late Devonian age, and 700 feet of Madison limestone and of Mississippian age. The overlying rocks belong to the Amsden formation, which is intergradational from the Mississippian (?) to the Pennsylvanian and the Tensleep sandstone of Pennsylvanian age. The Amsden formation lies unconformably on the Madison limestone, consists of red shales and siltstones, gray limestones and sandstones, and ranges from 230 to 280 feet in thickness. The Tensleep sandstone, which is as much as 120 feet thick but is missing locally, consist of gray to yellowish-gray sandstone and a few thin beds of dolomite and chert. Overlying the Tensleep sandstone and separated from it by an erosional unconformity are the Permian Embar formation and the Triassic Chugwater formation. The Embar and Chugwater formations were mapped separately only in the southwestern part of the area where the Embar consists of 100 feet of dolomite, limestone, and red siltstone and sandstone. Elsewhere, a zone of redbeds, gypsum, and thin beds of limestone is seemingly the Embar equivalent, but the zone is too thin to map as a formation and was included in the base of the Chugwater formation. The Chugwater formation consists of 350 to 500 feet of red sandstone and siltstone and gypsum. About 150 feet of red siltstone and sandstone, limestone, and gypsum belonging to the Piper formation of Middle Jurassic age overlies the Chugwater formation. In central Montana the Piper is separated from rocks as old as Mississippian by an extensive unconformity, but in the area adjacent to the Bighorn Mountains the Piper is seemingly conformable above the Chugwater. About 300 feet of light olive-gray to olive-brown calcareous shale belonging to the Upper Jurassic Rierdon formation overlies the Piper, and nearly 200 feet of yellowish-gray to grayish-green sandstone and siltstone and light olive-gray shale of the Upper Jurassic Swift formation overlie the Rierdon. Glauconite-bearing marine beds of the Swift formation grade upward into continental sandstones and siltstones of the overlying upper Jurassic Morrison formation. The upper part of the Morrison is largely variegated shales which are commonly concealed, and the total thickness of the formation ranges from less than 100 feet to about 250 feet.

The Lower Crataceous Cloverly formation is 400 feet or less thick. It contains a basal lenticular member named the Pryor conglomerate member, a middle zone of variegated beds, and an upper zone of interbedded siltstones, shales, and sandstones. Where the Pryor member is missing, variegated beds in the upper part f the Morrison cannot be distinguished from beds of similar lithology in the Cloverly, and the two formations were mapped together. The Lower Crataceous Thermopolis shale, which is about 450 feet thick, consists of dark-gray shale and interbedded bentonite. A zone of gray sandstone dikes about 150 feet above the base is correlated with the Newcastle sandstone of the Powder River Basin and the Muddy sandstone in the Bighorn Basin. Overlying the Thermopolis shale is the Mowry shale which is characterized by abundant fish scales and numerous layers of siliceous shale and siltstone. The Mowry is 325 to 400 feet in thickness and contains several beds of bentonite. It is uppermost formation in the Lower Cretaceous series. A conformable sequence above the Mowry shale of about 4,000 feet of shales, siltstones, and sandstones underlies the Great Plains region. Included in this sequence are the Frontier formation, Cody shale, Parkman sandstone, and Bearpaw Shale, all of Late Cretaceous Age. These formations belong to the Colorado and Montana groups. The basal few feet of the nonmarine Hell Creek formation, which is equivalent to the Lance formation and younger than the Montana group, occurs in the northeast corner of the mapped area. The Frontier formation, about 250 feet thick, comprises dark-gray partly sandy shale and interbedded bentonite. Overlying the Frontier is the Cody shale which consists of 2,600 feet of dark-gray concretionary partly sandy shale and interbedded bentonite. It has been divided into 7 members, the lower 4 belonging to the Colorado group and the upper 3 to the Montana group. From base to top, the members of the Cody shale are (a) an unnamed member 200 feet thick; (b) the Greenhorn calcareous member 60 to 100 feet thick; (c) the Carlile shale member about 280 feet thick; (d) the Niobrara shale member 400 feet thick; (e) the Telegraph Creek member 750 feet to 850 feet thick; (f) a shale member equivalent in age to the Eagle sandstone about 375 feet thick; and (g) the Claggett shale member about 350 feet thick. Above the Cody shale is the Parkman sandstone which comprises 100 feet of silty and sandy shale overlain by 150 feet of massive and thick-bedded yellowish-gray and greenish-gray sandstone. The Bearpaw shale, which is the uppermost formation of the Montana group, is exposed only in the northeastern corner of the area. It is composed of dark-gray shale 850 feet thick that has many beds of bentonite in the middle. A few feet of greenish sandstone, siltstone, and shale belonging to the Hell Creek formation overlie the Bearpaw in the northeastern corner of the area. Six well-developed stream terraces, the highest two of which may be late Tertiary in age, extend along the Bighorn River. These and correlative terraces in tributary stream valleys have a 25-foot thick veneer of limestone and volcanic rock gravel. Several surfaces, which were mapped as pediments, in the southwestern part of the area slope rather steeply away from the Pryor Mountains and are covered with limestone gravel and boulders washed from the Pryor Mountains. Several erosional surfaces in the Great Plains area have little covering other than reworked shale and gravel washed from nearby terraces, and these surfaces were mapped as undifferentiated Quaternary surfaces. The folding and main deformation of the mountains occurred during early Tertiary time after the deposition of all the sedimentary formations of the area. The domes and anticlines in the plains region may have formed during this same period of orogeny as they trend parallel to the northern end of the Bighorn Mountains which is itself the northward plunging end of a long anticline. Structural closure on the domes is small except for Soap Creek dome, and faults are simple and of relatively small displacement except for the Sykes Springs fault zone near the southern tip of the Pryor Mountains. Black oil has been produced from the Soap Creek oil field, which was first drilled in 1921, and gas for the town of Hardin is supplied from the Hardin gas field. Thick beds of bentonite in the Cretaceous formations and limestone in the Carboniferous strata may some day be of economic importance. (Abstract by USGS. As printed in US Geological Survey Bulletin 1026) (156)

HERPETOFAUNA

Baum, Ryan E., Peterson, Charles R. 2002. 2001 Progress report of occurrence, distribution, and habitat relationships of amphibians and reptiles in Bighorn Canyon. 89 pages (Unpublished).
Preliminary survey of amphibians and reptiles in Bighorn Canyon during the summer of 2001 (157)

Corn PS. 2000. Amphibian declines: review of some current hypotheses. In: Sparling DW, Bishop CA, Linder G, editors. Ecotoxicology of amphibians and reptiles. Pensacola FL: Society of Environmental Toxicology and Chemistry. p 639-672.
Abstract in Progress (158)

Koch, E. D. , Peterson, C. R. . 1995. Amphibians and reptiles of Yellowstone and Grand Teton National Parks. University of Utah Press, Salt Lake City.
Description, distribution, and natural habitat for each species, with color photos, simple identification key, range maps, (160)

Muths, E., P.S. Corn, A.P. Pessier, and D.E. Green. Evidence for disease-related amphibian decline in Colorado. Conservation Biology (Submitted).
The recent discovery of a pathogenic fungus (Batrachochytrium dendrobatidis) associated with declines of frogs in the American and Australian tropics, suggests that at least the proximate cause, may be known for many previously unexplained amphibian declines. We have monitored boreal toads in Colorado since 1991 at four sites using capture–recapture of adults and counts of egg masses to examine the dynamics of this metapopulation. Numbers of male toads declined in 1996 and 1999 with annual survival rate averaging 78% from 1991 to 1994, 45% in 1995 and 3% between 1998 and 1999. Numbers of egg masses also declined. An etiological diagnosis of chytridiomycosis consistent with infections by the genus Batrachochytrium was made in six wild adult toads. Characteristic histomorphological features (i.e. intracellular location, shape of thalli, presence of discharge tubes and rhizoids) of chytrid organisms, and host tissue response (acanthosis and hyperkeratosis) were observed in individual toads. These characteristics were indistinguishable

from previously reported mortality events associated with chytrid fungus. We also observed epizootiological features consistent with mortality events associated with chytrid fungus: an increase in the ratio of female:male toads captured, an apparent spread of mortalities within the metapopulation and mortalities restricted to post metamorphic animals. Eleven years of population data suggest that this metapopulation of toads is in danger of extinction, pathological and epizootiological evidence. (Abstract by Muths et al as printed in Biological Conservation uncorrected proof). indicates that B. dendrobatidis has played a proximate role in this process. (161)

Patla, D. A. , Peterson, C. R. . 1999. Amphibians of Yellowstone: are amphibians declining in Yellowstone National Park?. Yellowstone Science. 7 1: 2-11.

The studies of amphibians and reptiles made by Frederick B. Turner in the mid 1950's provide baseline data for studying changes in the Park's populations and habitat. Lessons learned include the importance of viewing populations in the context of the local landscape; site fidelity may account for finding amphibians in disturbed areas; absence of historical information often makes judgments of species abundance difficult; development has costs beyond those usually considered; and above all, raw data should be retained in a safe place for the use of future investigators. Includes historical summaries, recommendations for future study. (162)

Peterson, C. R. , Koch, E. D. , Corn, P. S. 1993. Forty years of change in amphibian populations and habitats in Yellowstone and Grand Teton National Parks. Pages ? in No Editor/Author. Symposium on amphibian monitoring in western national parks; annual meeting of the Northwestern Veterbrate Biology, Astoria, Oregon, March 1993.

To determine long-term changes in amphibian populations in Yellowstone and Grand Teton National Parks, we revisited sites in 1991 that had been sampled in the 1950's. The most striking result of these comparisons was the extent of human modification of several of the sites. The Soldier Creek area, where Turner studied the demography of spotted frogs (Rana pretiosa), has been fragmented by gravel and paved roads which apparently have separated one of the main breeding ponds from the creek. A mark/recapture study conducted in July and August indicated that the spotted frog population there has decreased by 75-85%. Similarly, the construction of buildings, roads, and changes to the Jackson Lake dam have so modified Carpenter's best studied sites that meaningful comparisons can not be made. Based on these experiences, we recommend that the National Park Service identify the locations of past studies and consider this information when making land use decisions. We also recommend that researchers carefully consider the probability of disturbance (vs. convenience) when selecting sites for future monitoring or research studies. (Abstract by Peterson et al as printed in Abstracts of the Annual Meeting of the Society of Northwestern Vertebrate biology). (163)

HUMAN

Bearss, E.C. 1970. Bighorn Canyon National Recreation Area, Montana-Wyoming: History basic data. Volumes 1 and 2. U.S. Dept. Int., Natl. Pk. Serv., Office of History and Historic Architecture, Eastern Serv. Ctr. 687 pp. and unnumb. Plates.

Abstract in Progress (164)

Hansen, A.J., R. Rasker, B. Maxwell, J.J. Rotella, J. Johnson, A. Wright, U. Langner, W.B. Cohen, R.L. Lawrence, and M.P.V. Kraska. 2002. Ecological causes and consequences of Demographic Change in the New West. BioScience 52:151-162.

Abstract in Progress (168)

Nelson, J. D. , et al. Tailings and Mine Waste '96; proceedings of the third International Conference on Tailings and Mine Waste, Fort Collins CO, 16-19 Jan 1996. Balkema, Rotterdam. The Yellowstone Research Library (YRL) has a couple papers pertaining

Abstract in Progress (204)

Patten, D. T. . 1991. Human impacts in the Greater Yellowstone Ecosystem: evaluating sustainability goals and eco-redevelopment. Conservation Biology. 5 3: 405-411.

The Greater Yellowstone Ecosystem is composed of a mosaic of national parks, forests, wildlife refuges, and private lands, each managed with different goals. Perturbations, both natural and anthropogenic, influence these areas. Maintaining naturalness and sustaining the systems within the Greater Yellowstone Ecosystem are desired assessment endpoints in determining the need for ecosystem redevelopment. Ecosystem degradation is a natural response to human impacts, and evaluation of degradation relative to management goals can be used to determine the acceptability of the goals and potential for eco-redevelopment. Goals may range from maintaining very natural sustainable ecosystems to developing sacrifice areas for heavy tourist use or oil development. To evaluate human impacts in the Greater Yellowstone Ecosystem, management goals for all systems should be reexamined to determine whether the original goals remain appropriate and whether some level of eco-redevelopment is necessary to achieve these or newly established goals. Special attention should be given to impacts of interactive and cumulative human activities. (170)

Rasker, R. , Hackman, A. . 1996. Economic development and the conservation of large carnivores. Conservation Biology. 10 4: 991-1002.

"Employment and income trends in counties of NW Montana were also analyzed. It was found that protecting wildland
habitat for large carnivores is detrimental to a region's economy although enough counterevidence is presented to suggest an alternative hypothesis: the protection of wilderness habitat that sustains wild carnivores such as grizzly bears (Ursus arctos horribilis) and wolves (Canis lupus) does not have a detrimental effect on local or regional economies. Evidence presented suggests that economic growth is stimulated by environmental amenities. Further, use studies in southern British Columbia and Alberta in Canada and the Greater Yellowstone region, in the USA, where environmental protection has been explicitly recognized as an economic development strategy, suggest that environmental protection and economic development are complementary goals. " (171)

Watson, Alan E. 2000. Wilderness use in the year 2000: Societal changes that influence human relationships with wilderness. In: Cole, David N.; McCool, Stephen F.; Freimund, Wayne A.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference – Volume 1: Changing perspectives and future directions; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-0-VOL-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, RMRS.pg 53-60.

The purpose of this paper is to extend a synthesis of knowledge about wilderness visitors and their visits developed in 1985. At that time, visitor research was in decline, and there was very little ability to understand trends. Over the last 15 years, wilderness visitor research has been initiated at many places in the U.S. where no previous studies had been completed. There have also been several studies specifically aimed at providing comparisons over time. Although review of these studies has concluded that very little has changes about how we describe visitors, their visits or their preferences for management, limited data suggest that the way visitors relate to wilderness has changed and will continue to change well into the next century. (Abstract by Watson as printed in RMRS-P-15-VOL-4) (174)

INSECT

Christiansen, T. A. . 1996. Terrestrial litter invertebrate communities in Yellowstone National Park. Yellowstone Science. 4 2: 2-3.

Forest and sagebrush litter habitats were severely damaged during the 198 fires, and had not recovered 7 years later. The role of invertebrates in ecosystems is not yet well known. (176)

Ivie, M. A. . 1993. Biodiversity of insect fauna, pre and post burn: comparison between the 1970's and 1993-4. Investigator's Annual Report.

Abstract in Progress (177)

Lowrie, D. C. . 1989. A study of invertebrates of burned and unburned sagebrush grassland communities after the 1988 Yellowstone fires. Investigator's Annual Report.

A study of invertebrates of burned and unburned sagebrush grassland communities after the 1988 Yellowstone fires. (178)

Opler, P. A. 1995. Species richness and trends of western butterflies and moths. Pages 172-174 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

The authors have conducted a study of species richness in butterflies and three moth families covering 17 western states and 5 western subregions. Species richness of western moths and butterflies (Lepidoptera) is often closely related to plant diversity so these invertebrates are important indicators of environmental change. Opler identifies possible threats to western butterflies and moths including overgrazing, urbanization, and excessive controlled burns. He links management that produces high Lepidoptera species richness with management that also favors natural ecosystem processes. (179)

Swetnam, T.W., and A.M. Lynch. 1993. Multi-century, regional-scale patterns of western spruce budworm outbreaks. Ecological Monographs 63: 399-424.

Tree-ring chronologies from 24 mixed-conifer stands were used to reconstruct the long-term history of western spruce budworm (Choristoneura occidentalis) in northern New Mexico. Temporal and spatial patterns of budworm infestations (within-stand occurrences) and outbreaks (more-or-less synchronous infestations across many stands) were investigated to identify local-scale to regional-scale forest disturbance patterns. Nine regional-scale outbreaks were identified

from 1690 to 1989. One ancient stand of Douglas-fir trees (Pseudotsuga menziessii) exceeding 700 yr in age revealed that budworms and overstory trees can coexist for extraordinary lengths of time. Using spectral analysis we found that the regional outbreak record contained important cyclical components with periods varying from ≈ 20 to 33 yr. The statistically significant ($P<.05$) but variable periodicity of regional outbreaks suggests the forest-budworm dynamic is pseudoperiodic (i.e., a stable limit cycle of damped oscillator perturbed by noise).
Duration of infestations within stands was ≈ 11 yr and has not obviously changed in the 20th century; however, infestations tended to be more synchronous among stands in this century than during earlier centuries. Regional budworm activity was low from the mid-1920s to late 1930s and mid-1960s to late 1970s, and the most recent outbreak, beginning in the late 1970s, was unusually severe. These results, and contrasting infestation patterns in mountain ranges with different land use histories, generally support a hypothesis that human-induced changes in Southwestern forest have led to more widespread and intense budworm outbreaks in the late 20th century.
Despite human-induced changes in the 20th century, climate variation also appears to have been important to budworm regimes in this century as well as in earlier times. Regional outbreaks in the 20th century tended to occur during years of increased spring precipitation, and decreased budworm activity coincided with decreased spring precipitation. No clear association with temperature was identified. Comparisons of regional outbreak history since AD 1600 with a reconstruction of spring precipitation from limber pine (Pinus flexilis) ring width chronologies also shows that periods of increased and decreased budworm activity coincided with wetter and drier periods, respectively. This finding contrasts with results from shorter time-scale studies conducted in northwestern U.S. and Canada (western spruce budworm) and eastern Canada (spruce budworm C. fumiferana), where low precipitation and/or warmer temperatures were generally associated with outbreaks. Different patterns of budworm population response to changing moisture regimes might be due to differences in regional forest-budworm systems, or to differences in the spatial and temporal scales of observation. We conclude that changes in forest structure in the southwestern U.S. may have shifted the spatial and temporal pattern of budworm outbreaks. The dynamic behavior and statistically significant association between multicentury, regional budworm and climate time series also suggest that complex budworm dynamics are driven by a combination of internal and external factors. (Abstract by Swetnam and Lynch as printed in Ecological Monographs). (180)

LANDSCAPE

Good, John M. and Keneth L. Pierce. 1996. Interpreting the landscapes of Grand Teton and Yellowstone National Parks: Recent and Ongoing Geology. Grand Teton Natural History Association, Moose, WY.

Abstract in Progress (181)

Knight, D. H. 1994. Mountains and plains: the ecology of Wyoming landscapes. Yale University Press, New Haven, Conn. 338 pp.

Abstract in Progress (182)

Romme, W. H. , Knight, D. H. . 1982. Landscape diversity: the concept applied to Yellowstone Park. Bioscience. 32 8: 664-670.

Changes in landscape patterns may influence a variety of natural features including wildlife abundance, nutrient flow, and lake productivity. Data suggest that cyclic changes in landscape diversity occur on areas of 100 km^2 in Yellowstone National Park. When properly managed, large wilderness areas provide the best and probably the only locale for studying the kind of landscape changes that occurred for millenia in presettlement times. (183)

Shovic, H. F. , Maynard, C. L. , Nesser, J. A. . 1999. Greater Yellowstone area landscapes and soils: Project Description and Progress to date. Part One: the report. usfs, Natural Resources Conservation Service.

The Greater Yellowstone Area (GYA) Landscape Modeling Project is a cooperative effort between the Forest Service (Washington Office-ECOMAP, Region One, Two, Four, the Gallatin National Forest, and the Rocky Mountain Research Station), the Natural Resources Conservation Service, and the National Park Service (Yellowstone National Park.) Other supporting agencies include the Montana Natural Resources Information System-Montana State Library, and the Montana Natural Heritage Program. ...There is a critical need in the GYA to be able to study and manage changes and events that occur across administrative boundaries..There is a need for consistently-compiled resource themes (based on ecological principles) for the entire area to provide a basis for cross-boundary analyses both for scientific and management purposes. .." (184)

Turner, M. G. , et al. 1993. A revised concept of landscape equilibrium: Disturbance and stability on scaled landscapes. Landscape Ecology. 8 3: 213-227. no luck yet

Temporal and spatial scales of disturbance and recovery are often confounded in discussions of landscape equilibrium. We developed a broad framework for the description of landscapes that separates the spatial and temporal scales of disturbance and recovery and predicts the resultant dynamics of a landscape. Two key parameters representing time and space are used to describe potential disturbance dynamics. The temporal parameter, T, is the ratio of the disturbance interval (i.e., time between successive disturbance events) to the time required for a disturbed site to recover to a mature stage. The spatial parameter, S, is the ratio of the size of the disturbance to the size of the landscape. The use of ratios in both parameters permits the comparison of landscapes across a range of spatial and temporal scales. A simple simulation model was developed to explore the implications of various combinations of S and T. For any single simulation, disturbances of a fixed size are imposed at random locations on a gridded landscape at specified intervals. Disturbed sites recover deterministically through succession. Where disturbance interval is long relative to recovery time and a small proportion of the landscape is affected, the system is stable and exhibits low variance over time (e.g., northeastern hardwood forests). These are traditional "equilibrium" systems. Where disturbance interval is comparable to recovery time and a large proportion of the landscape is affected, the system is stable but exhibits large variance (e.g., subalpine forests in Yellowstone Park). Where disturbance interval becomes much shorter than recovery time and a large proportion of the landscape is affected, the system may become unstable and shift into a different trajectory (e.g., arid ecosystems with altered fire regimes). This framework permits the prediction of disturbance conditions that lead to qualitatively different landscape dynamics and demonstrates the scale-dependant nature of concepts of landscape equilibrium. (Abstract by Turner et al as printed in Landscape Ecology). (185)

Anderson, Stanley H., Hubert, Wayne A., Patterson, Craig, Redder, Alan J., Duvall, David. 1987. Distribution of vertebrates of the Bighorn Canyon National Recreation Area. Great Basin Naturalist. 47 3: 512-521.

During a survey of the vertebrates in the Bighorn Canyon National Recreation Area, 46 mammal, 210 bird, 9 reptile, 5 amphibian, and 28 fish species were found. Habitat structure and moisture were two environmental variables associated with species numbers across this 1820-ha area. Eight distinct habitats were evaluated. In coniferous forests, 27% of the birds and 54% of the mammals were observed. Sagebrush/grasslands and upland shrublands were very arid and had relatively few vertebrates. Five introduced game birds occurred in sagebrush habitat. Riparian and wetland habitats had the largest number of unique vertebrates, 38 and 77 respectively. The establishment of Bighorn Lake in 1968 influenced the fisheries in streams and rivers as 10 introduced fish species are now there. (188)

MAMMAL

Beauvais, G.P. 1977. Mammals in fragmented forests in the Rocky Mountains: Community structure, habitat selection, and individual fitness. PhD. Diss. University of Wyoming, Laramie.

Chapter 1: We determined that species richness of mammal sin winter did not change along the major micro- and macrohabitatal gradients produced by clearcutting. However, habitat changes accompanying clearcutting allowed common habitat generalist to replace rarer, boreal adapted species. Distributions of small species were most affected by variations in microhabitat structure, whereas larger species responded to both micro- and macrohabitat variations. Persistent clearcutting of Rocky Mountain forests, especially on isolated mountain ranges, threatens to reduce mammal diversity at a regional scale. Chapter 2: Using data collected across a wide range of environmental variation, including a range of clearcut densities, we developed models predicting the probability of occurrence of each or 15 mammal species. For each species 1 model used microhabitat attributes and 4 models used macrohabitat attributes as predictors Macrohabitat models were developed at different spatial scales and compared on the basis of statistical significance and predictive success. Managers can use these models to estimate mammal distributions under current and predicted habitat conditions.
Chapter 3: We investigated the relationships between abundance, lipid content, litter size, and habitat structure for the southern red-backed vole (Clethrionomys gapperi). At small spatial scales, abundance and lipid content were weakly correlated; at larger scales, they were strongly correlated. Neither abundance nor lipid content were correlated with indices of litter size. Gradients of habitat structure did not predict abundance, lipid content, or litter size. Water content predicted lipid content in non-pregnant adults, and live mass predicted reproductive output in adult females. Chapter 4: Using artificially created mammal trails in snow, we found that trail visibility varies with track size, exposure to weather, and time since snowfall. We propose a new measure of trail detectability that controls for this variation and can produce more comparable indices of relative occurrence from snow-tracking data. Chapter 5: We tested the accuracy of estimates of trapping sampling effort from 2 different formulas. A simple correction for sprung traps improved estimated of sampling effort, and controlled for site-specific rates of trap-springing. Failure to use this correction can seriously bias comparisons of relative abundances estimated from trapping data. (Abstract by Beauvais as printed in Mammals in

fragmented forests in the Rocky Mountains: Community structure, habitat selection, and individual fitness). (189)

Bogan, M.A., and P.M. Cryan, 2000, The Bats of Wyoming IN Choate, J. R., Reflections of a naturalist : papers honoring Professor Eugene D. Fleharty: Hays, KS, Fort Hays Studies, Special Issue 1, p. 71-94.

We examined 1280 bats of 12 species submitted to the Wyoming State Veterinary Laboratory (WSVL) for rabies testing between 1981 and 1992. The most abundant species in the sample was Myotis lucifugus, followed by Eptesicus fuscus, Lasionycterus noctivagans, M. ciliolabrum, and M. volans. Using the WSVL sample and additional museum specimens, we summarized available records and knowledge or 17 species of bats in Wyoming. Records of the WSVL show that, between 1981 and 1992, 113 bats actually tested positive for rabies. We examined 45 of those rabies-positive bats; E. fuscus had the highest incidence (60%) in the sample, followed by L. noctivagans (11%) and L. cinereus (9%). (Abstract by Bogan and Cryan as printed in Reflections of a naturalist: papers honoring Professor Eugene D. Fleharty). (657)

Butts, T. W. . 1995. Bats of Yellowstone Park and vicinity. Investigator's Annual Report.

Abstract in Progress (190)

Clark, T.W. 1973b. Local distribution and interspecies interactions in microtines, Grand Teton National Park, Wyoming. Great Basin Naturalist 33:205-17.

Some ecological relationships and interspecies interactions (i.e. habitat, foods, and reproduction) between Microtus pennsylvanicus pullatus, M. montanus nanus, M. longicaudus mordex, and Clethrionomys gapperi galei were investigated in Grand Teton National Park, Wyoming. Trapping was conducted from June-July, 1968 and May-July, 1969 yielding 110 M.p.p., 171 M.m.n., 17 M.l.n. and 41 C.g.g. Six plant communities were defined structurally; all communities contained voles but varied considerably in number of species and individuals. Analyses of stomach contents showed similar diets. Embryo counts indicated that there was no significant interspecies differences in litter sizes. Females of all species were pregnant in about equal proportions. Almost all adult males showed descended testes and were reproductively active. Testicular and seminal vesicle weights and lengths fluctuated. M.p.p. mean body weights were largest: M44.7g (N=31). F38.1g (N=29); this was nearly twice the mean weights of C.g.g.: M20.4g (N=7). F23.3g (N=3). Weights for M.m.n. and M.l.m. fell between these extremes and were similar to each other. Trends in differential habitat use were clearly demonstrated and evidence suggests the four microtines are at least partially incompatible. (Abstract by Clark as printed in The Great Basin Naturalist). (191)

Clark, T.W. and M.R. Stromberg. 1987. Mammals in Wyoming. University of Kansas Museum of Natural History, Public Education Series no. 10. University Press of Kansas, Lawrence.

Abstract in Progress (526)

Craighead, Karen. 1991. Large mammals of Yellowstone and Grand Teton National Parks. Yellowstone Association for Natural Science, History, and Education, Yellowstone NP, WY.

Guidebook to Yellowstone and Grand Teton large mammals including reproductive biology, habitat, food habits, enemies, and tracks. (192)

Gompper, M., P. B. Stacey, and J. Berger. 1997. Conservation implications of the natural loss of Lineages in Wild Birds and Mammals. Conservation Biology 11:857-867.

Because populations in zoological parks and nature reserves often are derived from only a few individuals, conservationists have attempted to minimize founder effects by equalizing family group sizes and increasing the reproductive contributions of all individuals. Although such programs reduce potential losses of genetic diversity, information is rarely available about the actual persistence of family groups or genetic lineages in populations. In the abscesses of such data, it can be difficult to weigh the importance of human intervention in the conservation of small populations. Separate long-term studies of two mammals, North American bison (Bison bison) and the white-nosed coati (Nasua narica), and a bird, the Acorn Woodpecker (Melanerpes formicivorus), demonstrate differential extinction of genetic lineages. Irrespective of the mechanisms affecting population structure, which may range from stochastic environmental events to such behavioral phenomena as poor intrasexual competitive abilities, our results show that lineages can be lost at rapid rates from natural populations. A survey of comparable studies from the literature indicates that the loss of matrilines over the course of the study varies from 3% to 87% in wild mammals and from 30% to 80% in birds, with several small mammals losing approximately 20% of matrilines per year of study. These lineage extinctions were not an artifact of the length of the study or the generation time of the species. Such rapid losses of lineages in less than 20-year periods in natural populations suggest that efforts to maintain maximal genetic diversity within populations may not always reflect processes that occur in the wild. Conservation biologists need to give further thought to the extent to which parity among genetic lines should be a primary goal of management of captive and small wild populations. (Abstract by Gompper et al as printed in Conservation Biology). (193)

Hadly, E.A. and Brian A. Maurer. 2001. Spatial and temporal patterns of species diversity in montane mammal communities of western North America. Evolutionary Ecology Research 3: 477-486.

We present the results of the first analysis of distributional patterns of the same taxa across thousands of kilometres and thousands of years, which demonstrate that the exponents for the power relationships in space and time are similar. In both space and time, the distribution of mammalian taxa of the Great Basin and Rocky Mountains follows a ‘nested subset’ pattern. We conclude that species identities and their relative abundances are non-random properties of communities that persist over long periods of ecological time and across geographic space. This is consistent with species abundance contributing heavily to evolutionary patterns, and allows predictions of how species within communities will respond to future global change. (Abstract by Hadley and Maurer as printed in Evolutionary Ecology Research). (194)

Jannett, FJ. 1982. Nesting patterns of adult voles, Microtus Montanus, in field populations. Journal of Mammalogy. 63 3: 495-498.

Jannett describes data collected from a field study of female/male relationships among montane voles (Microtus montanus) and a short review of a field study on the meadow vole (Microtus pennsylvanicus). Male and female relations are perhaps the least known aspects of small mammal behavior. He recites field methods involved in the project focusing on male territoriality and female birthing. It was found that cohabitation of adult female and male montane voles is rare in summer and fall with some explainable exceptions in spring. (532)

Kotliar, N. B., B. W. Baker, A. D. Whicker, and G. Plumb, 1999, A Critical Review of Assumptions About the Prairie Dog as a Keystone Species: Environmental Management, v. 24, p. 177-192.

Prairie dogs (Cynomysspp.) have been labeled as keystone species because of their influence on biological diversity and ecosystem function. However, the validity of several assumptions used to support keystone status is questionable. We review the strength of the evidence and the magnitude of the prairie dog's effects on ecosystem structure and function. We use this review to reevaluate the keystone role for prairie dogs. Our goal is to encourage sound management of the prairie dog ecosystem by improving the ecological foundation of their keystone status. Our review confirms that prairie dogs affect a number of ecosystem- level functions but that their influence on prairie vertebrates may be less than previously suggested. Species richness and abundance patterns were variable among plants, mammals, and birds and were not consistently higher on prairie dog colonies compared to uncolonized areas. In addition, only nine of the 208 species listed in the literature as observed on or near prairie dogs colonies had quantitative evidence of dependence on prairie dogs. Abundance data indicated opportunistic use of colonies for an additional 20 species. A total of 117 species may have some relationship with prairie dogs, but we lacked sufficient data to evaluate the strength of this relationship. The remaining 62 species may be accidental or alien to the system. Despite our conclusion that some prairie dog functions may be smaller than previously assumed, collectively these functions are quite large compared to other herbivores in the system. We suggest that prairie dogs also provide some unique functions not duplicated by any other species and that continued decline of prairie dogs may lead to a substantial erosion of biological diversity and landscape heterogeneity across prairie and shrub-steppe landscapes. Thus, we concur that keystone status for prairie dogs is appropriate and may aid conservation efforts that help protect species dependent on prairie dogs and support other important ecosystem functions. (Abstract by Kotlier et al. as printed in Environmental Management). (654)

Maehr, D. editor. 2002. Large Mammal Restoration in North America: ecological and sociological considerations in the 21st century. Island Press, Washington, D.C.

Abstract in Progress (187)

Newmark, W. D. . 1986. Species-area relationship and its determinants for mammals in western North American national parks. Biological Journal of the Linnean Society of London. 28: 83-98.

Parks were evaluated for species richness, elevation, latitude, vegetative cover types, and species-area for area analysis. Study relevant to reserve design and preservation of biological diversity. Includes general data for Olympic National Park, WA. (195)

Patterson, Craig T. 1985. Bird and mammal inventory for the Bighorn Canyon National Recreational Area. Wyoming Cooperative Fishery and Wildlife Research Unit, Laramie, WY.

Abstract in Progress (196)

Pattie, D.L. and N.A.M. Verbeek. 1967. Alpine mammals of the Beartooth Mountains. Northwest Science 41:110-17.

A great expanse of alpine environment is included in six closely associated plateaus of the Beartooth Mountains in the Custer National Forest, Carbon County, Montana, and the Shoshone National Forest, Park County, Wyoming (Figure 1). McChesney (1879) first described a few of the mammals inhabiting the Beartooth Mountains, Bailey (1930) a few of the alpine forms in Yellowstone National Park to the west, and Hoffmann and Taber (1960) the dwarf shrew (Sorex nanus) taken in the Beartooth Mountains. Long (1965) indicated no one has described in detail the mammalian fauna of the extensive alpine areas in this part of Montana and Wyoming. This paper is a contribution on the mammals of this major biotic community, the alpine zone, defined as that area which is altitudinally above regions of normal tree growth and includes areas of krummholz-"the crooked wood"-making up part of the forest-tundra ecotone. (Abstract by Pattie and Verbeek as printed in Northwest Science). (653)

Pinter, A.J. 1988. Multiannual fluctuations in precipitation and population dynamics of the montane vole Microtus montanus. Canadian Journal of Zoology 66(4):2128-32.

The montane vole, Microtus montanus, exhibits multiannual fluctuations in population density in northwestern Wyoming. Multiannual fluctuations in precipitation during May were also observed in the area. For data from the past 19 years, there is a significant negative correlation between cycle phases of May precipitation and of population density. Peak precipitation in May (1970, 1974, 1977, 1980, 1984) was correlated in the same year with the decline phase in the population cycle. A trough in the May precipitation cycle (1969, 1973, `976, 1979, 1983, 1985) was correlated in the same year with a population peak. It is hypothesized that spring precipitation may contribute to the population dynamics of Microtus montanus in north-western Wyoming by influencing the survival and reproductive success of these rodents at a critical time, the onset of the breeding season. (Abstract by Pinter as printed in Canadian Journal of Zoology). (197)

Singer, F. J. , Schreier, W. , Oppenheim, J. , Garton, E. O. . 1989. Drought, fires, and large mammals. Bioscience. 39 10: 716-722.

Yellowstone National Park is renowned for its fauna of diverse and numerous large mammals. This article focuses on elk, because they are overwhelmingly the dominant park ungulate both in number and total mass. In early 1988 on the northern winter range, there were five times as many elk as all other types of ungulates combined. At the time of the 1988 drought and fires in Yellowstone, studies of the northern range were reevaluating the success of the natural regulation experiment. Extensive burning in 1988 occurred on five out of the seven elk summer ranges. All four of the elk winter ranges had from 2-50% of their areas burned. No previously published study has documented burning effects on such a large scale across the entire year-round ranges of several large elk herds. (198)

Smith, D.W. 1998. Beaver Survey in Yellowstone National Park. Mammoth, WY. YCR-NR-93-3.

The second parkwide aerial count of active beaver (Castor candensis) colonies was conducted in Yellowstone National Park in late October 1998. Flying time for the survey was 18.7 hours, slightly more than the 14.9 hours in 1996. Total number of colonies counted with a food cache was 51. Eighty percent of the beaver colonies were found at three locations: 1) the Madison-Grayling Creek-lower Gallatin River drainages; 2) the upper Yellowstone River from the Southeast Arm or Yellowstone Lake to Thorofare; and 3) the Bechler area. Average density of colonies per stream kilometer in these three areas was 0.23. The densest areas of beaver occupation in the park were found in the Yellowstone River delta and along a short section of the Madison River. Other locations where beaver colonies were found were Harlequin Lake, Shoshone Lake, Slide Lake, the Gallatin River, the Snake River, Outlet Creek, and Obsidian Creek. Beaver sign but no food cache was found at Heart Lake, the Lamar Valley, and Thorofare. Like the first survey in 1996, most observed beaver colonies were associated with willows (Salix spp.). (Abstract by Smith as printed in YCR-NR-99-3). (199)

Spildie, D.R. 1994. The density and distribution of small mammals in Grand Teton National Park, Wyoming. M.S. Thesis. University of Wyoming, Laramie, WY. 115 p.

I live-trapped small mammals in Grand Teton National Park during the summers of 1990 and 1991. In 1990, I sampled five burned and adjacent unburned sites of different ages to determine community response to post-fire succession. Of eight species captured, the deer mouse (Peromyscus maniculatus) and the southern red-backed vole (Clethrionomys gapperi) were most common: the deer mouse in open habitats and early successional seres; the red-backed vole in mature forests. Species diversity was higher in unburned forests, but density and diversity were related to the successional status of the sites, except for higher densities of deer mice in recent burns. In 1991, trapping was conducted in seven habitats along an elevational gradient and in the same sites at Huckleberry Mountain that were trapped in 1990. Nine small mammal species were captured in the elevational sites. Deer mice were the most numerous and were caught in all sites. The red-backed vole was also common but was only found in mature coniferous forest. Discriminant analysis of microhabitat variables allowed prediction of trap success at a significant level in the elevational sites. (Abstract by D.R Spilde, as printed in M.S. Thesis.) (200)

Streubel, D. P. . 1989. Small mammals of the Yellowstone ecosystem. Roberts Rinehart, Boulder CO.

Abstract in Progress (202)

Wood, M. A. . 1981. Small mammal communities after two recent fires in Yellowstone National Park. M.S. Thesis, Montana State University, Bozeman, MT.

The small mammals, their food habits, and their food resources were studied during the summers of 1978 and 1979 on two burns and two adjacent spruce-fir, lodgepole pine forest sites in Yellowstone National Park. The Divide site burned in 1976, and the Trail Creek site burned in 1974. A study plot was established in each burn and control site, and the small mammals were sampled by snap-trapping and pitfall traps twice each summer. Stomach contents were analyzed. Quantitative data were obtained on plant coverage, concealment cover (measured by a cover board), arthropod diversity and soil seed and fungal sclerotia numbers. (534)

Worthington, David J. 1991. Abundance and Distribution of Bats in the Pryor Mountains of South Central Montana and North Eastern Wyoming. University of Montana, Missoula, MT.

This report documents the results of a study on bat occurrence in the Pryor Mountains of south central Montana that was initiated in 1989. (203)

Youmans, C. C. . 1979. Characteristics of pocket gopher populations in relation to selected environmental factors in Pelican Valley, Yellowstone National Park. M.S. Thesis, Montana State University, Bozeman, MT.

Objectives of this study were to select specific representative sites in Pelican Valley on which pocket gopher numbers could be quantified, monitored, and compared with data gathered concurrently on vegetative composition, standing crop, soil moisture, soil texture, and snow melt phenology. Changes in pocket gopher numbers were analyzed by gathering data on pocket gopher natality, sex ratios, age structure, annual population turnover, recruitment, period of peak parturition, and home range size. Frequency of infection with the parasitic nematode Capillaria hepatica, average weights, and composition of a pocket gopher cache were also determined. Field work was conducted from June to September in 1977 and from June to October in 1978. (535)

RIPARIAN

Akashi,Y. 1988. Riparian vegetation dynamics along the Bighorn River, Wyoming. M.S. Thesis, Univ. WY, Laramie. 245pp.

Changes in the riparian vegetation mosaic during the last 49 years were studied along the Big Horn River near Lovell, WY. The results revealed a decline in Populus deltoides woodland area and an increase in shrubland area, particularly shrublands dominated by Tamarix chinensis and Rhus trilobata. Major causes for the changes are discussed and future changes are predicted. (205)

Chadde, S.W., P.L. Hansen, and R.D. Pfister. 1988. Wetland plant communities of the northern range, Yellowstone Naional Park. School of Forestry, University of Montana, Missoula, Mont. Contract report for National Park Service on file at Mammoth Hot Springs.

Abstract in Progress (206)

Duffy, W. G. . 1999. Wetlands of Grand Teton and Yellowstone National Parks: Aquatic Invertebrate Diversity and Community Structure. Pages 733-756 in Batzer, D. P. , Rader, R. B. , Wissinger, S. A. . Invertebrates of Freshwater Wetlands of North America: Ecology and Management. Wiley, New York.

Aquatic invertebrates were sampled monthly from May through September in six wetlands in Yellowstone and Grand Teton National Parks during 1995. Wetlands sampled exhibited semipermanent, seasonal, and temporary hydrologic regimes. Physical and chemical characteristics of wetland water were similar, except for specific conductance, which was either low (<60 mS cm -1), intermediate (270-550 mS cm -1), or high (>900 mS cm -1). A total of 187 taxa of aquatic invertebrates were identified from all samples. Almost 70 percent of the taxa collected had not been reported previously in either park. Taxa richness was greatest in semipermanent wetlands and least in temporary wetlands. Among all wetlands, monthly mean abundance ranged from 18,041 m-2-335,975 m-2. Food webs of semipermanent wetlands were most complex, while those in temporary wetlands were most simple. (Abstract by Duffy as printed in Aquatic Invertebrate Diversity and Community Structure). (207)

Elliot, C.R. and M.M. Hektner. 2000. Wetland resources of Yellowstone National Park. Yellowstone National Park, WY. 32pp. (Online). Available: http://www.nps.gov/yell/publications/pdfs/wetlands/index.htm.

Abstract in Progress (208)

Girard, M., D.L. Wheeler, and S.B. Mills. 1997. Classification of riparian communities on the Bighorn National Forest, USDA Forest Service R2-RR-97-02.

Abstract in Progress (210)

Hupp, C. R. and W. R. Osterkamp. 1996. Riparian vegetation and fluvial geomorphic processes. Geomorphology 14: 277-295.

Riparian vegetation and fluvial-geomorphic processes and landforms are intimately connected parts of the bottomland landscape. Relations among vegetation, processes, and landforms are described here for representative streams of four areas of the United States: high-gradient streams of the humid east, coastal-plain streams, Great Plains streams, and stream channels of the southwestern United States. Vegetation patterns suggest that species distributions in the humid easy are largely controlled by variation in fluvial geomorphic processes (cycles of degradation and aggradation) in response to increases in channel gradient associated with channelization. Similarly, riparian vegetation of Great Plains streams may be controlled by fluxes in sediment deposition and erosion along braided streams. Patterns of riparian vegetation in semi-arid regions may be most closely related to patterns of water availability, unlike most other streams in more humid environments. Channel-equilibrium conditions control stability of the coincident fluvial landform and attendant vegetation pattern throughout the continent. In most situations, riparian-vegetation patterns are indicative of specific landforms and, thus, of ambient hydrogeomorphic conditions. (Abstract by Hupp and Osterkamp as printed in Geomorphology). (329)

Kay, C.E. 1994. The impact of native ungulates and beaver on riparian communities in the Intermountain West. Natural Resources and Environmental Issues 1:23-44.

This paper reviews the impact native ungulates, primarily elk and moose, and beaver can gave on riparian communities in the Western United States. In Yellowstone National Park and in other areas where ungulates are not managed, repeated browsing has reduced tall willow, aspen, and cottonwood communities by approximately 95 percent since the late 1800s. Native ungulates can also severely reduce or eliminate palatable grasses and forbs from herbaceous riparian communities. By eliminating woody vegetation and security cover and by altering plant-species composition, native ungulates can alter bird, mammal, and aquatic communities. They can even negatively affect endangered species like grizzly bears for which riparian areas provide critical habitat. In many respects, excessive use by native ungulates is similar to overgrazing by domestic livestock. Beaver is a keystone species that alters the hydrology, energy flow, and nutrient cycling of aquatic systems. Unlike ungulates, which tend to degrade riparian habitats, beaver actually, create and maintain riparian areas. Beaver dams not only impound water but they also trap sediments that raise the water table and allow the extension of riparian communities into former upland areas. By trapping silt over thousands of years, beaver have actually created many of the West's fertile valleys. Prior to the arrival of Europeans, Western streams supported large populations of beaver. During one five-day period in 1825, Peter Skene Ogden's fur brigade trapped 511 beaver. Today, state and federal land-management agencies are using beaver to restore damages riparian areas. Beaver, however, can become a nuisance when they dam irrigation facilities, plug highway culverts, or fell streamside trees valued by landowners. (Abstract by Kay as printed in Natural Resources and Environmental Issues). (211)

Keigley, R.B. 1998. Architecture of cottonwood as an index of browsing history in Yellowstone. Interm. J. Sci. 4(3/4):57-67.

I determined the history of browsing elk (Cervus elaphus) on narrowleaf cottonwood (Populus angustifolia) at a site in northern Yellowstone National Park (YNP). I aged cottonwoods in three stands by dendrochronology and classified them into four architectural categories that I postulated were produced of four browsing regimes: 1) uninterrupted-growth type (light-to-moderate browsing), 2) arrested-type (intense browsing), 3) retrogressed-type (a change from light-to-moderate browsing to intense browsing), and 4) release-type (a change from intense browsing to light-to-moderate browsing). Cottonwood trees established prior to 1947 were of uninterrupted-growth type architecture. Trees established between 1947 and 1968 were of uninterrupted- and release-type architectures. With the exception of individuals short enough to be protected from winter browsing by snowpack, all individuals established after 1968 were of arrested- and retrogressed-type architectures. Cottonwoods in the study area experienced the following browsing history: (1) light-to-moderate until 1951, (2) intense from 1952 to 1962, (3) light-to-moderate from 1963 to 1974, and (4) intense since 1975. Architecture-based methods can be used to determine the rank order sequence in which elk currently prefer different species of browse. Once determined, that rank order sequence can be used to test competing hypotheses about the declines in woody plants in YNP. (Abstract by Keigley as printed in the Intermountain Journal of Sciences). (212)

Knopf, F. L., and T. E. Olson. 1984. Naturalization of Russian-olive: implications to Rocky Mountain wildlife. Wildlife Society Bulletin. 12: 289-298
aturalization and spreading of exotic woody vegetation in riparian zones have received much attention in recent years. This attention has been directed primarily at salt-cedar tamarisk (Tamarix pentandra) in south-western states (e.g. Robinson 1965, Horton 1977). Tamarisk along the lower Colorado River does not compare favorably with native woody vegetation as avian habitats (Anderson et al. 1977) and, without control, will completely displace native riparian vegetation with time (Horton 1977). Russian-olive (Elaeagnus angustifolia) is a native of Europe and western Asia introduces into North American prior to 1900. The spreading, sometimes shrub-like, tree tolerates a wide range of soil and moisture conditions, adapting to local conditions throughout the western United Sates from Minnesota to Kansas to the Pacific Ocean (Borell 1976). The history of Russian-olive in western states was summarized by Christensen (1963). Briefly, the species was being planted extensively in residential areas by 1900. Russian-olives were first reported escaping cultivation in 1924 in Utah, 1925 in Nevada, 1942 in Arizona and California, 1952 in Idaho, 1954 in Colorado, and 1960 in New Mexico and Texas. Russian-olive has been promoted, especially by soil conservationists, as an excellent planting for windbreaks, erosion control, and wildlife enhancement (Van Dersal 1939, Wilson 1944, Billings 1945, Graham 1949, Borell 1976). Over 50 species of birds and mammals use Russian-olive as a source of food or cover (Borell 1976). Recently, we noticed that extensive, virtually monotypic stands of Russian-olive have invaded riparian zones of some western (Green, Missouri, Snake) river systems. These riparian zones provide critical, limited habitats for many vertebrate species in the West (Johnson and Jones 1977). This paper (1) alerts natural resource conservation personnel to naturalization of Russian-olive in the West, (2) reports on the avian and mammalian associations of monotypic stands of Russian-olive in 3 western states, (3) discussed similarities of those associations to vertebrate communities occurring in nearby native riparian and upslope vegetation types using the analytical approach discussed by Samson and Knopf (1982), and (4) speculates on implications of the continued naturalization of Russian-olive to Rocky Mountain

avian and mammalian communities. (Abstract by Knopf and Olson as printed in Wildlife Society Bulletin). (330)

Naiman, R.J. and H. Decamps. 1997. The ecology of interfaces: riparian zones. Annu. Rev. Ecol. Syst. 28(1):621-658.

Riparian zones possess an unusually diverse array of species and environmental processes. The ecological diversity is related to variable flood regimes, geographically unique channel processes, altitudinal climate shifts, and upland influences on the fluvial corridor. The resulting dynamic environment supports a variety of life-history strategies, biogeochemical cycles and rates, and organisms adapted to disturbance regimes over broad spatial and temporal scales. Innovations in riparian zone management have been effective in ameliorating many ecological issues related to land use and environmental quality. Riparian zones play essential roles in water and landscape planning, in restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts. (Abstract by Naiman and Decamps as printed in the Annual Review of Ecological Systems). (213)

Nilsson, C., R. Jansson, and U. Zinko. 1997. Long-term responses of river-margin vegetation to water level regulation. Science. 276. pp. 798-800.

The long-term effect of water-level regulation on riparian plant communities was assessed for storage reservoirs and run-of-river impoundments. Soon after the onset of regulations, there were few species and sparse vegetation cover, regardless of whether the new water level intersected former upland or riparian vegetation. IN the longer-term, an impoverished vegetation was maintained by storage reservoirs, whereas in run-of-river impoundments, some community characteristic deteriorated and others recovered compared to adjacent free-flowing rivers. (Abstract by Nilsson as printed in Science). (335)

Patten, D.T. 1998. Riparian ecosystems of semi-arid North America: diversity and human impacts. Wetlands 18(4):498-512.

Riparian ecosystems in the semi-arid West of North America are diverse but have many similarities. The mountainous landscape with wide range of latitude, longitude, and elevation offers diverse opportunities for streamside vegetation. All riparian ecosystems in the region are dependent on supplemental water, usually from the shallow, valley alluvial aquifer. Western riparian ecosystems provide several ecological services. They stabilize streambanks, trap sediment, improve water quality, and help control or modulate hydrologic processes. They function as habitat for many western animal species, serving as a small mesic island or strip within an arid landscape. They also serve as recreational sites for humans. Riparian systems are controlled by interacting hydrologic and geomorphic processes. Floods may alter river channel characteristics and the extent of riparian vegetation while enhancing recruitment of riparian species and recharging the alluvial water table. Geomorphic features, such as canyons and valleys, control the size of the riparian zone, as well as depth of the water table. Driving variables may differ from the north to south, especially hydrology. For example, northern riparian zones are influenced by ice scour, while southern zones often have flash floods. Riparian systems occur along spatial and temporal gradients. Along elevational gradients, riparian vegetation may change from simple deciduous forests to mixed deciduous to coniferous and possibly alpine wetlands. Differences among channel, terrace, and upland plant communities decrease with increasing elevation as moisture stress decreases. Temporal gradients occur within a location in the riparian zone as early pioneer communities such as cottonwood/will give way to late successional communities such as mesquite or sagebrush, often a consequence of sediment accumulation. Many similarities among western riparian ecosystems exist because several dominant genera (e.g., Populus) are common throughout the West, and many geomorphic and hydrologic processes that influence riparian establishment are similar. Western riparian ecosystems have been greatly altered by human activity. Major factors include natural resource use, urbanization, alteration of stream flows through dam construction and ground-water withdrawal, modification of biotic conditions through grazing, agriculture, and introduction of non-native species, and alteration within watersheds. Better understanding of the ecology of western riparian ecosystems will increase potential for restoration and protection of remaining areas. (Abstract by Patten as printed in Wetlands).#237 We contrast the geochemistry of the Madison drainage, which has high concentrations of geothermal features, with the Lamar drainage of Yellowstone National Park, USA, and trace the consequences of geochemical differences through abiotic and biotic linkages in the ecosystem. Waters in the geothermal-dominated drainage contained anomalously high levels of fluoride (F) and silica (SiO2). Soils, stream sediments, and surface waters that interact or mix with geothermal waters, in turn, had elevated F and SiO2 concentrations compared to similar samples from the Lamar drainage. The geochemical differences were reflected in the chemistry of forage plants, with some plants from geothermally influenced areas containing four- to eightfold higher concentrations of F and SiO2 than similar plants in the Lamar drainage. Geothermal heat reduced snowpack, and we found that elk (Cervus elaphus) concentrated in these refugia as snowpack increased each winter. The consequent high dietary intake of F in animals associated with the geothermal areas was confirmed by the finding that bone samples from elk living in the Madison drainage contained sixfold higher concentrations of F than samples collected from animals wintering in the Lamar drainage. High F exposure resulted in compromised dentition due to fluoride toxicosis, which was undoubtedly exacerbated by the abrasive action of silica. The consequent accelerated and aberrant tooth wear resulted in early onset of senescence, reduced life span, and an abbreviated age structure. We speculate that these altered demographics, combined with spatial heterogeneity of snowpack, will result in increased vulnerability of this large herbivore population to wolf predation and less resiliency to compensate demographically for predation. (Abstract by Garrott et al as printed in Ecosystems). (214)

Rood, S. B. and J. M. Mahoney. 1993. River Damming and riparian cottonwoods: management opportunities and problems. In Riparian Management: common threads and shared interests. USDA Forest Service General Technical Report RM-226. pp 134-142.

Abstract in Progress (337)

Shafroth, P. B., J. M. Friedman, and L. S. Ischinger. 1995. Effects of salinity on establishment of Populus fremontii (cottonwood) and Tamarix ramosissima (saltcedar). Great Basin Naturalist. 55 (1): 58-65.

The exotic shrub Tamarix ramosissima (saltcedar) has replaced the native Populus fremontii (cottonwood) along many streams in southwestern United States. We used a controlled outdoor experiment to examine the influence of river salinity on germination and first-year survival of P. fremontii var. wislozenii (Rio Grande cottonwood) and T. ramosissima on freshly deposited alluvial bars. We grew both species from seed in planters of sand subjected to a declining water table and solutions containing 0, 1, 3, and 5 times the concentrations of major ions in the Rio Grande at San Marcial, NM (1.2, 10.0, 25.7, and 37.4 meq 1-1;0.11, 0.97, 2.37, and 3.45 dS m-1). Germination of P. fremontii declined by 35% with increasing salinity (P=.008). Germination of T. ramosissima was not affected. There were no significant effects of salinity on mortality or above- and belowground growth of either species. In laboratory tests the same salinities had no effect on P. fremontii germination. P. fremontii germination is more sensitive to salinity outdoors than in covered petri dishes, probably because water scarcity resulting from evaporation intensifies the low soil water potentials associated with high salinity. River salinity appears to plat only a minor role in determining relative numbers of P. fremontii and T. ramosissima seedlings on freshly deposited sandbars. However, over many years slat becomes concentrated on floodplains as a result of evaporation and salt extrusion from saltcedar leaves. T. ramosissima is known to be more tolerant of the resulting extreme salinities than P. fremontii. Therefore, increases in river salinities could indirectly contribute to the decline of P. fremontii forest by exacerbating salt accumulation of floodplains. (Abstract by Shafroth et al as printed in Great Basin Naturalist). (339)

Stettler, R.F., H.D. Bradshaw,Jr., P.E. Heilman, and T.M. Hinclley, eds. 1996. Biology of Populus and its implications for Management and Conservation. Ottawa: NRC Research Press, National Research Council of Canada.

Abstract in Progress (215)

Youngblood, Andrew P., Padgett, Wayne G., Winward, Alma H. 1985. Riparian community type classification of eastern Idaho-western Wyoming. Intermountain Forest and Range Experiment Station, R4-Ecol-85-01, Ogden, UT.

A community type classification is presented for the riparian ecosystems of eastern Idaho and western Wyoming. This hierarchical taxonomic system of vegetation classification is based on existing riparian vegetation, and uses data from 469 sample stands. (216)

SOIL

Marston. 1990. Runoff and Soil Loss Following the 1998 Yellowstone Fires. Great Plains-Rocky Mountain Geographical Journal. Vol. 18. No. 1. The Future University of Nebraska at Kearney. Kearney State College. 8pp.

Fires burned 570,000 hectares (1.41 million acres) in the Greater Yellowstone Area during 1988 with accelerated runoff and soil loss as an expected result. A rainfall simulator was used in the summer of 1989 to measure runoff and soil loss on plots representing a range in geologic substrate, logging history, fire intensity, and geomorphic-pedologic conditions. Water repellent soils were common, producing high rates of runoff and soil loss for the experimental rainfall event. Rates of soil loss were highest on sites where litter cover was minimal, percent silt content in soils was high, and logging had occurred. Rated of runoff and soil loss did not exhibit statistically significant differences between glacial till and volcanic terrain, but the logging-fire history was associated with statistically significant differences in soil loss. Soil loss was highest on sites which had been logged before the 1988 fires and then burned, and this was attributed to the higher fuel load on the forest floor. (Abstract by Obia. As printed in Great-Plains Rocky Mountain Geographical Journal.) (219)

Miller, S. L. , Stanton, N. L. , Williams, S. E. . 1992. Effects of fire on ectomycorrhizal fungi, spore dispersal and dependent flora establishment in soils.

The objectives of this study were to determine spore dispersal agents and fungi present or introduced at the burned sites, determine the effect that mycorrhizal fungi have on conifer seedling recruitment after fire, and to determine vascular plant species dependent upon mycorrhizae for establishment. Hypothesis tested included: 1) Mycorrhizal fungi are primarily responsible for affecting conifer recruitment and secondary succession in the burns; 2) The mycorrhizal status of conifer seedlings affects their survivability, growth and development in the burns; 3) Mycorrhizal fungal spores and other propagules dispersed by small mammals into the burns affect the mycorrhizal status of conifer seedlings. The study area is located along the John D. Rockefeller Memorial Highway between Yellowstone and Grand Teton National Parks. (218)

Rodman, A. W. , Shovic, H. F. , Thoma, D. P. . 1996. Soils of Yellowstone National Park. Yellowstone Center for Resources, Yellowstone National Park.

Abstract in Progress (220)

Shovic, H. F. . 1996. Landforms and associated surficial materials of Yellowstone National Park. Yellowstone Center for Resources, Yellowstone National Park

This inventory describing "meso" level landforms(2.5 to 250 acres) and associated features for Yellowstone National Park, has possible application in many areas of natural resource management and analysis, from wetland mapping to fire-spread modeling, forest regeneration to wildlife habitat. (221)

West, N.E. 1990. Structure and function of soil microphytic crusts in wildland ecosystems of arid and semi-arid regions. Adv. Ecol. Res. 20:179-223.

Abstract in Progress (223)

Young, Jack F. 1982. Soil survey of Teton County, Wyoming, Grand Teton National Park Area. U.S. Department of Interior//Soil Conservation Service//National Park Service//Wyoming Agriculture Experiment Station, Washington, DC?.

This soil survey contains information that can be used in land-planning programs in Teton county, Grand Teton National Park Area, Wyoming. It contains predictions of soil behavior for selected land uses. The survey also highlights limitations and hazards inherent in the soil, improvements needed to overcome the limitations, and the impact of selected land uses on the environment. (224)

THREATENED & ENDANGERED

Clark, T. W. , et al. 1989. Rare, sensitive, and threatened species of the greater Yellowstone ecosystem. Northern Rockies Conservation Cooperative, Jackson, Wyoming.

brief description, history and recommendations for the species listed (225)

Consolo Murphy, S. L. . 1999. Threatened and Endangered Species; brief summary of status in Yellowstone (rev.). ycr?, ynp?.

Brief status reports including population estimates. (226)

Dennis, B. , Munholland, P. L ., Scott, J. M. . 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs. 61 2: 115-143.

"Survival or extinction of an endangered species is inherently stochastic. We develop statistical methods for estimating quantities related to growth rates and extinction probabilities from time series data on the abundance of a single population. The statistical methods are based on a stochastic model of exponential growth arising from the biological theory of age- or stage-structured populations. The model incorporates the so-called environmental type of stochastic fluctuations and yields a lognormal probability distribution of population abundance. We provide example analyses of data on the Whooping Crane (Grus americana), grizzly bear (Ursus arctos horribilis) in Yellowstone, Kirtland's Warbler (Dendroica kirtlandii), California Condor (Gymnogyps californianus), Puerto Rican Parrot (Amazona vittata), Palila (Loxioides balleui), and Laysan Finch (Telespyza cantans). The model results indicate a favorable outlook for the Whooping Crane, but long-term unfavorable prospects for the Yellowstone grizzly bear population and for Kirtland's Warbler." (227)

Heidel, Bonnie, Fertig, Walter. Rare Plants of Bighorn Canyon National Recreation Area. Montana Natural Heritage Program, Helena, Montana.

Abstract in Progress (228)

Marriof, Hollis. 1993. Rare plant of Grand Teton National Park, final report. Wyoming Natural Diversity Database, Wyoming.

In 1989, Grand Teton National Park began a project with the Wyoming Natural Diversity Database to identify plant species of concern and their locations within the Park. The project objectives are to: produce a list of plant species of concern for GRTE (i.e. species requiring attention and possibly special management for continued viability), begin collecting data on location, habitat, population size, trends, threats and management needs within GRTE for species identified. (229)

Reading, Richard and Brian Miller, eds. 2000. Endangered animals: a reference guide to conflicting issues. Greenwood Press, Westport, CT.

Abstract in Progress (230)

THERMAL

Ball, J. W. , Nordstrom, D. K. , Jenne, E. A. , Vivit, D. V. . 1998. Chemical analyses of hot springs, pools, geysers and surface waters from Yellowstone National Park, Wyoming and vicinity, 1974-75. U. S. Geological Survey, Boulder CO.#98574

Gives analytical determinations for samples collected 1974-75. Water temperature, pH, Eh and dissolved O_2 were determined on-site. Flame atomic absorption spectrometry was used to determine concentrations of Li, Na, K, Ca and Mg. Ultraviolet/visible spectrophotometry was used to determine concentrations of Fe(II), Fe(III), As(III) and As(V). Direct current plasma-optical-emission spectrometry was used to determine the concentrations of B, Ba, Cd, Cu, Mn, Ni, Pb, Rb, Sr and Zn. (231)

Brock, T.D. 1994. Life at high temperatures. Yellowstone Association for Natural Science, History, and Education, Inc., Yellowstone National Park, Wyo. 31 pp.

Deals with the living organisms in Yellowstone National Park, and their great economic impact on society. There are microorganisms that live in the boiling waters and run-off channels of the geysers and hot springs. Although their color is visible to the naked eye, an individual microbial cell is so small as to be completely invisible. The microorganisms of the hot springs are mostly bacteria, but at the lower temperatures algae and protozoa are also present. (232)

Chester, C. C. . 1995. Biodiversity prospecting in Yellowstone National Park: management of Yellowstone microorganisms and the experience of the National Biodiversity Institute (INBio) of Costa Rico. Pages 16 in No Editor/Author. Biodiversity, ecology and evolution of thermophiles in Yellowstone National Park: overview and issues, Sept. 17-20, 1995 [abstracts of talks].

Microorganisms living in the thermal pools of Yellowstone National Park (YNP) represent a potential reservoir of scientific and economic value. One bacterium from the park, Thermus aquaticus, has already proven its commercial sales value in the range of over one hundred million dollars per year. None of the financial benefits from T. aquaticus, have gone back to YNP for the Park's mission of protecting biodiversity-including the microbial diversity of the Park. Some have criticized this, arguing that YNP should receive royalties for the commercial use of microorganisms found in the park. As of yet, however, YNP has not developed the institutional mechanisms to take fair advantage of its microbial resources. An institutional example for YNP lies in the National Biodiversity Institute (INBio) of Costa Rica, which has taken proactive steps to increase conservation through the sustainable use of Costa Rica's biological diversity. Partly because INBio conducts its "biodiversity prospecting" activities within Costa Rica's national parks and conservation areas, INBio's experience is directly relevant to the management challenges facing YNP. INBio's pilot projects in biodiversity prospecting focus on equitable benefits sharing arrangement that fulfill the needs of business, government, and conservation of biodiversity. INBio has already demonstrated that the commercial use of biodiversity can help support the protection of biodiversity. YNP should follow suit by developing policies and creating institutional capacity that enhance both industrial innovation and direct benefit to the national park system. (Abstract by Chester as printed in Biodiversity, Ecology and Evolution of Thermophiles in Yellowstone National Park: Overview and Issues). (233)

Clifton, C. G., Walters, C. C., Simoneit, B. R. T. . 1990. Hydrothermal petroleums from Yellowstone National Park, Wyoming, USA. Pages 169-191 in No Editor/Author. Organic matter in hydrothermal systems - maturation, migration and biogeochemistry; selected papers from the 3rd Chemical Congress of North American and the 195th ACS national Meeting. Pergamon, Oxford.

"In Yellowstone National Park, oil is actively discharging with thermal waters at several widely separated thermal areas. Samples from two locations were studied. Petroleum from Calcite Springs occurs as vapor condensates in steam vents. Detailed geochemical analyses show a complex origin for the petroleum fluid. Deeply buried, hydrothermally altered sedimentary rocks are believed to have contributed a high temperature pyrolysate consisting largely of polynuclear aromatic hydrocarbons and heterocyclic compounds. Shallow sedimentary rocks, which are also hydrothermally altered, have contributed large amounts of aromatic and polar compounds, as well as minor amounts of hydrocarbons. The Permian Phosphoria Formation is suggested as a likely source rock for the bulk of the oils. Autochthonous pyrolysates and lipids from thermally altered surface and near surface bacterial and land plant debris have also been

introduced to the vents by downward percolating meteoric water. The oil from Rainbow Springs is a highly paraffinic, low-S crude oil, depleted in light hydrocarbons. Unlike the Calcite Springs samples, the oil from Rainbow Springs is believed to have originated from a single sedimentary source rock with little or no hydrocarbon contributions from surface biota. " (234)

Des Marais, D. J. . 1996. Stable light isotope biogeochemistry of hydrothermal systems. Pages 83-98 in Bock, G. R. , Goode, J. A. . Evolution of hydrothermal ecosystems on earth (and Mars?). Wiley, New York.

Stable isotopic composition of the elements O, H, S and C in minerals can indicate the processes, including biological activity, of hydrothermal systems. Hydrothermal alteration of mineral values can be used to detect fossil systems. (235)

Fournier, R. O. 1989. Geochemistry and dynamics of the Yellowstone National Park hydrothermal system. Annn. Rev. Earth Planet. Sci. 17:13-53.

"Relatively dilute alkali-chloride waters at Norris Geyser Basin attain chemical equilibrium with reservoir rocks underground in a series of reservoirs at temperatures ranging from about 200 to 325 C. Reservoirs of acid-sulfate-chloride waters at >190-200 C also exist underground at Norris and there is episodic mixing (usually in the fall) of acid-sulfate-chloride and alkali-chloride waters. The rate of discharge of sulfate by the acid-sulfate-chloride water from deep in the system is large, and it is difficult to account for the generation of all of this type of water solely by present-day local oxidation of H2S that is carried in steam to the Earth's surface at Norris, followed by infiltration of acid-sulfate water back underground where it mixes with chloride-rich water. Additional sulfate may be generated by bacteria (sulfolobus) that consume native sulfur and liberate sulfuric acid in shallow underground environments. The source of native sulfur may be old solfataras in the Norris region, formed as a result of volcanic activity that produced silicic domes south of Norris, and that were subsequently covered either by later volcanic flows, or by glacial material deposited on hot ground. Another possibility, supported by (superscript 3)He/(superscript 4)He data is that a component of magmatic gas containing SO2 is entering parts of the Norris system and reacting with water to form H2SO4 and H2S." (236)

Garrott, R.A., L.L. Eberhardt, J.K. Otton, P.J. White, and M.A. Chaffee. 2002b. A geochemical trophic cascade in Yellowstone's Geothermal Environments. Ecosystems. 5(7):659-666.

We contrast the geochemistry of the Madison drainage, which has high concentrations of geothermal features, with the Lamar drainage of Yellowstone National Park, USA, and trace the consequences of geochemical differences through abiotic and biotic linkages in the ecosystem. Waters in the geothermal-dominated drainage contained anomalously high levels of fluoride (F) and silica (SiO2). Soils, stream sediments, and surface waters that interact or mix with geothermal waters, in turn, had elevated F and SiO2 concentrations compared to similar samples from the Lamar drainage. The geochemical differences were reflected in the chemistry of forage plants, with some plants from geothermally influenced areas containing four- to eightfold higher concentrations of F and SiO2 than similar plants in the Lamar drainage. Geothermal heat reduced snowpack, and we found that elk (Cervus elaphus) concentrated in these refugia as snowpack increased each winter. The consequent high dietary intake of F in animals associated with the geothermal areas was confirmed by the finding that bone samples from elk living in the Madison drainage contained sixfold higher concentrations of F than samples collected from animals wintering in the Lamar drainage. High F exposure resulted in compromised dentition due to fluoride toxicosis, which was undoubtedly exacerbated by the abrasive action of silica. The consequent accelerated and aberrant tooth wear resulted in early onset of senescence, reduced life span, and an abbreviated age structure. We speculate that these altered demographics, combined with spatial heterogeneity of snowpack, will result in increased vulnerability of this large herbivore population to wolf predation and less resiliency to compensate demographically for predation. (Abstract by Garrott et al as printed in Ecosystems). (237)

Hinman, N. W. . 1995. Geochemistry of hot spring sinters and microbial mats. Investigator's Annual Report.

Abstract in Progress (238)

Hugenholtz, P., C. Pitulle, K.L. Hershberger and N.R. Pace. 1998. Novel division level bacterial diversity in a Yellowstone hot spring. Journal of Bacteriology 180(2):366-376.

A culture-independent molecular phylogenetic survey was done on Octopus Pool. A majority (70%) of the sequence types found were affiliated with 14 previously recognized bacterial divisions (main phyla; kingdoms); 30% were unaffiliated with recognized bacterial divisions. The unaffiliated sequence types (represented by 38 sequences) nominally comprise 12 novel, division level lineages termed candidate divisions. (239)

Redmann, R. E. 1984. Tolerance of plants to environmental stresses around thermal areas in Yellowstone National Park. Investigator's Annual Report.

Abstract in Progress (240)

Reysenbach, A. L. and S. Cady. 2001. Microbiology of ancient and modern hydrothermal systems. Trends in Microbiol. 9: 79-86.

Hydrothermal systems have prevailed throughout geological history on earth, and ancient Archeaen hydrothermal deposits could provide clues to understanding earth's earliest biosphere. Modern hydrothermal systems support a plethora of microorgansims and macroorganisms, and provide good comparisons for paleontological interpretation of ancient hydrothermal systems. However, all of the microfossils associated with ancient hydrothermal deposits reported to date are filamentous, and limited stable isotope analysis suggests that these microfossils were probably autotrophs. Therefore, the morphology and mode of carbon metabolism are attributes of microorganisms from modern hydrothermal systems that provide valuable information for interpreting the geological record using morphological and isotopic signatures. (Abstract by Reysenbach as printed in Trends in Microbiology). (241)

Reysenbach, A.-L., M.A. Ehringer, and K. Hershberger. 2000. Microbial diversity at 83 C in Calcite Springs Yellowstone National Park, reveals a novel deeply rooted bacterial lineage and another member of the Korarchaeota.Extremophiles 4: 61-67.

The use of molecular phylogenetic approaches in microbial ecology has revolutionized our view of microbial diversity at high temperatures and led to the proposal of a new kingdom within the Archaea, namely, the "Korarchaeota." We report here the occurrence of another member of this archaeal group and a deeply rooted bacterial sequence from a thermal spring in Yellowstone National Park (USA). The DNA of a mixed community growing at 83 C, pH 7.6, was extracted and the small subunit ribosomal RNA gene (16S rDNA) sequences were obtained using the polymerase chain reaction. The products were cloned and five different phylogenetic types ("phylotypes") were identified: four archaeal phylotypes, designated pBA1, pBA2, pBA3, and pBA5, and only one bacterial phylotype, designated pBB. pBA5 is very closely related to the korarchaeotal phylotype, pJP27, from Obsidian Pool in Yellowstone National Park. The pBB phylotype is a lineage within the Aquificales and, based on 16S rRNA sequence, is different enough from the members of the Aquificales to constitute a different genus. In situ hybridization with bacterial-specific and Aquificales-specific fluorescent oligonucleotide probes indicated the bacterial population dominated the community and most likely contributed significantly to biogeochemical cycling within the community. (Abstract by Reysenbach et al as printed in Extremophiles). (242)

Shanks, W. C. , et al. 1998. Geology and geochemistry of hydrothermal systems in Yellowstone Lake. Pages 50 in No Editor/Author. Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts. Yellowstone Association, Yellowstone National Park.

The influence of sublacustrine vents on metal concentrations in Yellowstone Lake has been evaluated by collecting and analyzing water column profiles and hydrothermal vent samples. Metal analyses indicate that vents in West Thumb are enriched in As, Cs, Ga, Ge, Li, Mo, Na, Rb, Sb, and W whereas Mary Bay vents are enriched in Ba, Ce, Fe, La, Mn, and Y. The water column data indicate that these elements have higher concentrations in West Thumb and Mary Bay relative to those in Southeast Arm, outside the area of hydrothermal venting, and that the differences in element enrichments between the West Thumb and Mary Bay vents are reflected in the respective water columns. Hydrogen (dD) and oxygen isotope (d18O) analyses indicate that Yellowstone Lake waters fall on an evaporation trend relative to the global meteoric water line, indicating the lake is 5-15% evaporated relative to Yellowstone River influx. Hydrothermal vent H S and d34S values averaging 2.0% Dissolved SO4 in lake waters has d34^2S values averaging 2.6%, indicating predominance of volcanic sulfur sources. In general, Yellowstone Lake water and Yellowstone River overflow are strongly influenced by geothermally supplied metals and sulfur.

Lake bottom hydrothermal deposits occur near active hydrothermal vents in West Thumb, Mary Bay, and off Stevenson Island. Two types of hydrothermal deposits have been recovered. Siliceous deposits from Mary bay consist of up to meter-length aggregates of tubular to irregularly-shaped cm-diameter filled fluid "conduits." The outer surface of the conduits comprises soft to friable sediment which is progressively recrystallized and cemented by hydrothermal amorphous silica toward the inner wall of the conduits. These observations indicate that the hydrothermal deposits formed via fluid flow within sediments, and that sediments have subsequently been winnowed away, probably by slumping. The second type of deposit occurs near Bridger Bay at a water depth of 15 m, where a group of hard irregular spires up to 7 m tall and 1-2 m diameter project above a relatively flat sediment surface in a hydrothermally inactive area. These spires are siliceous sinter that is texturally similar to many subaerial hot spring deposits in YNP. The spires have an outer zone of amorphuous iron oxyhydroxides that is enriched in As, Ba, Co, Cu, Ga, Li, Mo, Ni, Sr, Tl, V and W. Geochemical modeling indicates that the Bridge Bay spires have grown up from the sediment-water interface by mixing of hydrothermal fluids with lake water. (Abstract by Shanks et al. As printed in

Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts) (243)

Ward, D. M., M. J. Ferris, S. C. Nold, and M. M. Bateson. 1998. A Natural View of Microbial biodiversity within hot spring cyanobacterial mat communities: an evolutionary ecology view. Microbiol. Mol. Biol. Rev. 62:1353-1370.

Abstract in Progress (245)

Wiegert, R. G. . 1995. Long-term measurement of the ecology of thermal communities. Investigator's Annual Report.

Abstract in Progress (246)

Zeikus, J. G. , Brock, T. D. . 1972. Effects of thermal additions from the Yellowstone geyser basins on the bacteriology of the Firehole River. Ecology. 53 2: 283-290.

A series of stations was established on the Firehole River where it flows through the main geyser basins of Yellowstone Park, and temperature, pH, alkalinity, conductivity, and phosphate were measured. (247)

UNGULATES

Boyce, Mark S., Metzgar, Lee H., Peters, J. Terry. 1991. Bighorn Sheep and Horses on the BICA: Wilderness or Pasture?. University of Wyoming NPS Research Center, Laramie WY.

In this paper we review the ecology and management of feral horses and bighorn sheep on the BICA and Pryor Mountain Wild Horse Range, and to present information on competition between these species that could be relevant to the management of these species on wilderness areas. We develop a model of competition between horses and bighorns and use this model to make predictions of the probable future dynamics of the system under various management alternatives. Finally, we discuss management implications in the context of Park Service policy regarding the management of exotic species. (248)

Brownell, Joan. Horse Distribution in the Pryor Mountains Region Preceding the Creation of the Pryor Mountain Wild Horse Range, 1999

Abstract in Progress (345)

Caslick, J., and E. Caslick. 1999. Pronghorn distribution in winter 1998-1999. National Park Service, YCR, Mammoth Hot Springs, Wyo. YCR-NR-99-2.

Covers mortality, estimates of herd size, recommendations, predators, maps of weekly distribution. (249)

Coughenour, M.B., and F.J. Singer. 1996. Elk population processes in Yellowstone National Park under the policy of natural regulation. Ecological Applications 6:573-593.

The interrelations of weather, plant production and abundance, and elk population dynamics on Yellowstone's northern winter range were examined for a 23-yr period when there was minimal human offtake from the herd. Significant correlations between precipitation and plant production, between elk population responses and precipitation, and between elk population responses and elk population density strongly suggested that forage limited elk population growth. Although population responses to density have been documented previously in Yellowstone, responses to precipitation have not. Correlations between elk population responses and annual precipitation were presumably consequences of plant growth responses to precipitation and subsequent effects on elk nutritional status. Population regulation was most consistently achieved through the responses of juveniles rather than adults. Winter mortality of juveniles was primarily correlated with precipitation. Adult mortality rates were not significantly correlated with elk numbers, but were correlated with precipitation. Per capita rate of increase was negatively correlated with elk number, but 55% of the variance was density-independent. There was evidence that winter weather affected the elk, but season-long weather indices had poor predictive power. A stage-structured population model using regression equations of mortality and recruitment rate responses to precipitation and elk numbers, predicted that the population could vary within a range of ?16,400 ? 2,500 sighted elk (mean ? 1 SD). (Abstract by Coughenour and Singer as printed in Ecological Applications). (250)

Garrott, R.A., L.L. Eberhardt, P.J. White, and J. Rotella. 2002a. Climate-induced variation in vital rates of an unharvested large-herbivore population. Canadian Journal of Zoology, in review.

Variation in vital rates of an unharvested elk (Cervus elaphus) population was studied using telemetry for 7 consecutive years, 1991–1998. We found pronounced senescence in survival rates, but no evidence for reproductive senescence. Prime-age females (<10 years old) experienced very high annual survival rates (mean = 0.97, SE = 0.02), with lower survival rates for senescent animals (10 years old; mean = 0.79, SE = 0.06). There was evidence that the severity of snowpack conditions had little effect on survival of prime-age animals except during the most extreme winter, while survival of senescent animals was progressively depressed as the severity of snowpack conditions increased. Reproductive rates remained essentially constant, near their biological maxima (mean = 0.91, SE = 0.02). Annual re cruitment was highly variable. Snowpack had a pronounced effect on recruitment (r2 = 0.91), the most severe snowpack conditions resulting in the virtual elimination of a juvenile cohort. Population estimates and recruitment rates obtained during this investigation and historic data collected from 1965 to 1980 support the premise that the population has been maintained in a dynamic equilibrium for at least three decades despite the stochastic effects of climate variation on vital rates. We conclude that the population is resource-limited, with variation about the equilibrium caused primarily by variable recruitment driven by stochastic annual snowpack. Abstract (251)

Gogan, P.J. , E.M. Olexa, T.O. Lemke, and K. Podruzny. 1999. Population dynamic of northern Yellowstone Mule Deer. In abstract and presentation, Northwest Section, The Wildlife Society. Intermountain Journal of Science. Vol 5, p. 50March.

We report trends in numbers and age and sex structure of mule deer wintering in the Gardiner Basin area of the northern Yellowstone winter range between 1987 and 1998. The ratios of fawns: 100 adults in early spring are related to an index of winter severity and its component parts. Early winter fawn: 100 adult ratios are related significantly to the winter forage index as predicted by previous spring precipitation. Spring fawn: 100 adult ratios are related significantly to an index of snow water equivalent and the overall winter severity index. Survival of adult female mile deer from 1993 to 1997 as determined from radiotelemetry averages 0.80 per year. Models of survival constrained by the components of the index of winter severity are all more parsimonious than a tear-varying survival model. We conclude that

variation in annual survival of adult females was a function of winter severity. (Abstract by Gogan et al as printed in the Intermountain Journal of Sciences). (252)

Gogan, P.J.P., J.A. Mack, W.G. Brewster, E.M. Olexa and W.E. Clark. 2001. Ecological studies of bison in the Greater Yellowstone Area: development and implementation. The George Wright Forum 18: 67–75.

Bison (Bison bison) of the Greater Yellowstone Area (GYA) are perhaps best known to the scientific community from the classic study of Meagher (1973) that reviewed their ecological status and management from the time of establishment of Yellowstone National Park in 1872 through the last National Park Service (NPS) removals of bison within the poark in 1966. Since the cessation of herd reductions in the park, bison numbers within Yellowstone increased (Dobson and Meagher 1996), as did range use (Meagher 1989b), including increased frequency and magnitude of movements beyond the park boundries in winter (Meagher 1989a; Pac and Frey 1991; Cheville et al. 1998). (Abstract by Gogan et al as printed in The George Wright Forum). (253)

Gogan, P.J.P., R.H. Barrett, W. Shook and T.E. Kucera. 2001. Control of ungulate numbers in protected areas. Wildlife Society Bulletin 29(4):1075-1088.

Successful long-term control of ungulate numbers within a protected area requires continuous review and refinement of management practices. Insight gained may have application to other sites. We evaluated management objectives and actions to control populations of exotic axis deer (Axis axis) and fallow deer (Dama dama) at Point Reyes National Seashore, California. Using records of numbers of each species culled from 1968 to 1996 and demographic data, we modeled each population's potential response to management actions and to the cessation of control in 1996. These simulations indicated that control measures hold numbers of both populations below ecological carrying capacity (K) and that populations of fallow and axis deer may have reached K within 5 to 13 years of ceasing control, respectively. We also simulated each population's response to removal of actual numbers of males killed but no females and actual numbers of females killed but no males from 1968 to 1996. Removing males only resulted in both populations reaching K. Removing females only lead to the extirpation of both populations. Cessation of control activities prior to removal of all females resulted in recovery of both populations. A team of personnel expended an average of 1.75 work-hours/deer to remove 1,182 exotic deer of both species from 1984 to 1994. The work effort required to remove ?2 deer/day reached as great as 20 hours/deer. Elimination of the axis deer population is feasible and likely a more cost-effective management alternative than continued population control. Elimination of fallow deer is potentially more difficult but may be more cost-effective than continuing control actions indefinitely. We recommend similar assessment s of management alternatives to those charged with controlling ungulate numbers in protected areas. (254)

Gudorf, Michelle, Sweanor, Patricia and singer, Francis, Bighorn Sheep Habitat Assessment of the Greater Bighorn Canyon National Recreation Area. 1996

Abstract in Progress (255)

Hobbs, N. T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management. 60 4: 695-713.

Emerging evidence suggests that indirect interactions between species may be more important than direct ones in determining ecosystem patterns and processes. The author reviews the indirect effects of ungulates on nutrient cycling, net primary production, and disturbance regimes in terrestrial ecosystems. (256)

Hobbs, N.T. and R.A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. J. Wildlife Management 48: 551-560.

Prescribed burning elevated the concentration of protein and in vitro digestible organic matter (IVDOM) in winter diets of mountain sheep (Ovis canadensis) and mule deer (Odocoileus hemionus) feeding in grassland and mountain shrub communities. We observed no effect of burning on ungulate nutrition during spring. In both communities, the magnitude of treatment effects tended to depend on the month we observed diets. Effects of burning on diet crude protein persisted for 2 years in both communities. Treatment effects on diet IVDOM lasted for 2 years in mountain shrub, but were absent during the 2nd year in grassland. Effects of fire on diet quality resulted form changes in ungulate diet selection rather than improvements in the quality of individual forages. Differences in the amount of green grass in ungulate diets accounted for much of the enhancement in diet quality we observed. We conclude that prescribed fire can improve winter habitats for mule deer and mountain sheep. (Abstract by Hobbs as printed in Journal of Wildlife Management). (257)

Irby, L. and J. Knight, eds. 1998. International symposium on bison ecology and management in North America. Mont. State Univ., Bozeman, MT.

"This proceedings provides papers and abstracts on the broad array of interest related to bison in North America. Categories include: bison ecology, management perspectives, genetics, physiology, paleontology, history, and disease. Recognizing the array of opinions related to bison management, the symposium committee has also included a "Viewpoints on Management" section to allow opininon papers to reflect some non-scientific ideas." (258)

Irby, Lynn R., Mackie, Richard J., Kissell, Robert E.=, Jr. 1994. Competitive interactions between Bighorn Sheep, Wild Horses, and Mule Deer in BICA and Pryor Mountain Wild Horse Range. Montana State University, Bozeman, MT.

This report summarizes a study which attempted to differentiate ecological requirements of bighorn sheep, feral horses, and mule deer. The objectives were to determine population estimates for mule deer; ascertain species habitat associations; describe intra and interspecific behavior; and to examine commonalities of food habits of the species. (259)

Keigley, R.B., and F.H. Wagner. 2000. What is “Natural”?: Yellowstone Elk Population—A case study. Integrative Biology. 1:133-148.

Ecology analyzes the structure and function of ecosystems at all points along the continuum of human disturbance, from so-called pristine forests to urban backyards. Undisturbed systems provide reference points at one end of the spectrum, and nature reserves and parks are highly valued because they can provide unique examples of such ecosystems. Unfortunately the concept of “natural” or pristine is not that easy to define. Indeed, although ecologists have considered pre-Columbian, western-hemisphere ecosystems to have been largely unaltered by human action, and have termed their state “natural” or “pristine,” evidence from archaeology challenges this view. U.S. and Canadian national parks are charged with preser5ving the “natural,” and thus need to be able to understand and manage for the “natural.” A pivotal “natural” question in Yellowstone National Park management is the size of the northern-range, wintering elk population at Park establishments in 1872, argued both to have been small and large. Integrating and quantifying several sources of evidence provides a consistent picture of a low population (ca. 5,000-6,000), largely migrating out of the northern range in winter, with little vegetation impact. If we accept this conclusion about what is natural for the Yellowstone ecosystem, then it dramatically alters how we view management alternatives for the Park, which currently supports a northern wintering herd of up to ~25,000 elk. (Abstract by Keigley and Wagner as printed in Integrative Biology). (260)

Laundre, J.W. 1994. Resource overlap between mountain goats and bighorn sheep. Great Basin Naturalist. 54(2):114-121.

Mountain goat (Oreanmnos americanus) and bighorn sheep (Ovis candanesis)ranges overlap substantially in northwestern United States and southwestern Canada. Resource overlap in food and habitat parameters is assumed, but the degree of overlap has not been estimated. Data from published separate and comparative studies on food and habitat use were used to calculate indices of resource overlap for goats and sheep. Indices of overlap for general forage classes (grasses, forbs, browse) were >0.90 in summer and winter for data based on pooled data from separate studies and in summer for data from comparative studies. In winter for comparative studies this overlap was 0.64. For studies where forage species were identified, estimates of resource overlap from separate studies were ~0.8 but were <0.5 for comparative studies. Indices of overlap for habitat variables were also low (<0.7) for comparative studies. It was concluded that possible overlap in food and habitat use by goats and sheep could be extensive; but in sympatric populations, resource overlap may be reduced substantially. (Abstract by Laundre as printed in Great Basin Naturalist). (261)

Meagher, M., and M. E. Meyer. 1994. On the origin of brucellosis in bison of Yellowstone National Park: a review. Conservation Biology 8:645-653.

"Brucellosis caused by Brucella abortus occurs in the free-ranging bison (Bison bison) of Yellowstone and Wood Buffalo National Parks and in elk (Cervus elaphus) of the Greater Yellowstone Area. As a result of nationwide bovine brucellosis eradication programs, states and provinces proximate to the national parks are considered free of bovine brucellosis. Thus, increased attention has been focused on the wildlife within these areas as potential reservoirs for transmission to cattle. Because the national parks are mandated as natural areas, the question has been raised as to whether Brucella abortus is endogenous or exogenous to bison, particularly for Yellowstone National Park. We synthesized diverse lines of inquiry, including the evolutionary history of both bison and Brucella, wild animals as Brucella hosts, biochemical and genetic information, behavioral characteristics of host and organism, and area history to develop an evaluation of the question for the National Park Service. All lines of inquiry indicated that the organism was introduced to North America with cattle, and that the introduction into the Yellowstone bison probably was directly from cattle shortly before 1917. Fistulous withers of horses was a less likely possibility. Elk on winter feedgrounds south of Yellowstone National Park apparently acquired the disease directly from cattle. Bison presently using Grand Teton National Park probably acquired brucellosis from feedground elk." (262)

Olexa, E.M., K.A. Keating, and P.J.P. Gogan. Bison habitat selection at the landscape level in Yellowstone National Park. In Conservation management of bison in northern landscapes: advances in ecology and epidemiology. (In prep.)

Abstract in Progress (263)

Ostovar, K. 1998. Impacts of human activity on bighorn sheep in Yellowstone National Park. M.S. Thesis, Mont. State. Univ., Bozeman, MT.

Seventeen years have passed since bighorn sheep (Ovis canadensis canadensis) in Yellowstone National Park (YNP) experienced massive Chlamydial-caused die-off. Currently no sign of Chlamydia or pneumonia is evident, thus other factors are considered to be limiting the population. The proposed changes to the Gardiner-Mammoth highway and the highway through Dunraven Pass could increase or decrease human disturbances to the core of the population of bighorn sheep. Approximately 65% of all observations on the Everts winter range occurred on top of McMinn Bench (along the proposed road route). One ewe group currently must cross the Gardiner-Mammoth highway to reach spring lambing grounds. The placement of the road onto McMinn Bench would impact at least 2 other populations of ewe groups and 2-3 populations of ram groups, which seek shelter, security, water, and minerals in the cliffs. Use of the Dunraven Pass road corridor was low and potential displacement from road changes would be minor. Disturbance events were recorded during behavioral observations. Human presence was recorded for 26% of all observations, with 25% of these resulting in disturbances. The percentage of overall human disturbances for all observations in each group was: McMinn Bench ewes 7.5%, McMinn Bench rams 4.6%, Mount Washburn 4.3%, Deckard Flats 5.4%, Rattlesnake Butte 2.9%. The most disturbing human activity (based on overt reactions) was helicopter aircraft. To evaluate the effects of these human disturbances I used 3 non-invasive techniques that may be indicators of stress in bighorn sheep: behavioral activity levels, lungworm larvae shedding levels (LPG), and levels of hormone corticosterone. Most groups were not significantly different in degree of activity. Corticosterone levels did not correlate with LPG levels, suggesting that LPG may not be a good indicator of disturbances. Corticosterone differences in radio-collared and uncollared individuals were insignificant. Rams had significantly lower corticosterone levels than females ($F=4.56$, $P=.0334$). Levels dropped during winter and increased dramatically for both rams and ewes during the month of May, suggesting that measures of corticosterone may be more indicative of social stress than climatic or nutritional stress during the winter. McMinn Bench ewes had significantly higher levels of corticosterone than Rattlesnake Butte ewes ($F=6.31$, $P=.0125$) corresponding with distances to road, activity levels, human disturbance rates and possibly reproductive success. (Abstract by Ostovar as printed in his MSU Thesis). (264)

Schullery, Parul and Lee Whittlessey. In press. Mountain goats in the Greater Yellowstone Ecosystem: a prehistoric and historical context. Great Basin Naturalist.

Because the relatively recent colonization of portions of Yellowstone National Park by introduced mountain goats (Oreamnos americanus) from public game lands in Montana raises important policy and management questions for the park, it is necessary to understand the prehistoric and early historical record of mountain goats in the Greater Yellowstone Ecosystem. We reviewed previous paleontological, archeological, and historical studies of goat presence and examined a large body of historical material for evidence of goats. Native mountain goat range most closely approached the Greater Yellowstone Ecosystem to the west, but no modern authority claims goats were resident in the ecosystem in recent centuries. Historical accounts of goat presence in the region prior to 1882 (and thus prior to any known introduction of goats by Euro-Americans) are limited to one possible sighting by unreliable observers and a few casual mentions of goat presence by people of limited or unknown familiarity with the ecosystem. Other early observers in the region specifically stated that goats were not native. Between 1882 and 1926 other observers and residents agreed that mountain goats were not native to the park, or to the larger area around it. It is impossible to prove absolutely that there were no goats in the ecosystem prior to modern introductions, but historical evidence demonstrates that if present, such goats must have been exceedingly rare and uncharacteristically unsightable. National Park Service policy relating to exotic species developed gradually after the creation of Yellowstone National Park in 1872, moving from a general receptivity to introduction of at least some favored nonnative species to a general prohibition on all such introductions. Current policy, while disapproving of all nonnative species, seems to reserve special efforts at removal of nonnatives for those species that pose the greatest threat to native species and ecosystems. Current policy is not helpful in defining the minimum amount of evidence needed to prove a species was present or absent, or whether or not an introduced nonnative species is causing sufficient harm to justify its removal. (265)

Scott, M. D. , Geisser, H. . 1996. Pronghorn migration and habitat use following the 1988 Yellowstone fires. Pages 123-132 in Greenlee, J. M. . Ecological implications of fire in Greater Yellowstone; proceedings, Second Biennial Conference on the Greater Yellowstone ecosystem, Yellowstone National Park, September 19-21, 1993. International Association of Wildland Fire, Fairfield WA.

Preburn known pronghorn range was compared to postburn habitat use as monitored through 73 radiotelemetered pronghorns. Forest burns on the summer range were probably beneficial due to the clearing of new feeding areas and/or corridors to isolated habitat. Pronghorn wintering on the unburned permanent range between Mammoth and Reese Creek depended on big sagebrush for food, but the sagebrush has been declining in this area. (667)

Singer, F. J. . Effects of grazing by wild ungulates in Yellowstone National Park. U. S. Department of the Interior, National Park Service, Denver CO.

Abstract in Progress (269)

Singer, F.J., and R.A. Renkin. 1995. Effects of browsing by native ungulates on the shrubs in big sagebrush communities in Yellowstone National Park. Great Basin Natu. 55(3):201-212.

The effects of elk (Cervus elaphus), pronghorn (Antilocapra americana), and mule deer (Odocoileus hemionus) browsing on shrubs in big sagebrush (Artemisia tridentata) communities were monitored over a 31-year period in Yellowstone National Park. Ungulates were restricting Wyoming big sagebrush (spp. Wyomingensis) heights, size, and recruitment on the lower-elevation stratum only, while no such suppression was observed on the high-elevation stratum. Parallel increases in mountain big sagebrush (spp. vaseyana) densities and cover occurred over the study period on both browsed and unbrowsed sites at the higher-elevation stratum, although big sagebrush, green rabbitbrush (Chrysothamnus viscidiflorus), and horsebrush (Tetradymia canescens) were slightly taller and crown sizes were slightly larger on unbrowsed than browsed sites. Wyomingoming big sagebrush utilization (percent leader rise) was eight times higher (hivin x = 87 +- 7.2% by pronghorns, mule deer, and elk) on the low-elevation winter range stratum (the Boundary Line Area (BLA) portion of the winter range), while mostly mountain big sagebrush with leader use averaged only 11 +- 4.1% (nearly all by elk) on the high-elevation range stratum. In addition, annual aboveground biomass production of big sagebrush did not differ between browsed and unbrowsed study sites on the high-elevation stratum of the winter range. Population turnover was higher on browsed big sagebrush at the high-elevation plots; seedling germination and survival rates were higher on browsed plots versus unbrowsed plots. No difference was observed in percent dieback of big sagebrush adult plants between browsed and unbrowsed plots at the higher stratum. Browsing did not influence the Dumber of leaves or seedstalks per plant (P gt .05), but leaves averaged 45% longer and seedstalks 42% longer on browsed big sagebrush. Ungulate browsing, however, apparently suppressed production, germination, and survival of Wyoming big sagebrush on the low-elevation stratum. Numbers of Wyoming big sagebrush declined 43% and cover declined 29%, 1957-1990, on browsed sites on the BLA. Annual biomass production on browsed sites at the low-elevation stratum was only 6-35% that of unbrowsed sites, and big sagebrush recruitment was less on browsed sites. Percent leader use of big sagebrush did not differ between the period of ungulate reductions, 1962-1969, and the 1980s on the lower stratum (hivin x = 87% leader use), but utilization was less on higher portions of the winter range during the period of elk reductions (hivin x = 2%) than during the 1980s following cessation of elk controls (hivin x = 11%). (270)

Singer, Francis et al, Demographic Analysis, Group Dynamics and Genetic Effective Population Size in the Pryor Mountain Wild Horse Population, 1999

Data of Genetic Heterozygosity in the herd, reproductive success to conduct demographic analysis, estimate genetic effective size. (347)

Sloan, William, A Herd History of the Bighorn Sheep of Bighorn Canyon National Recreation Area, Montana and Wyoming, 1995

Abstract in Progress (266)

Taper, M.L., and P.J.P. Gogan. 2002. The northern Yellowstone elk: density dependence and climatic conditions. Journal of Wildlife Management 66:106-122.

We analyzed a time series of estimates of elk (Cervus elaphus) numbers on the northern Yellowstone winter range from 1964 to 1979 and 1986 to 1995 using a variety of discrete time stochastic population dynamic models. These models included adjustments for density, an increase in the are of winter range used by elk, lagged effects of the weather covariates of spring precipitation, snow depth and winter temperature, and the impacts of the 1988 drought and fires. An information-criteria-based model-selection process strongly supported evidence of density dependence. The best model, a Ricker model, distinguished between the 2 time periods. The bulk of the difference between the 2 periods is attributed to an increase in the amount of winter range used by elk. Inclusion of the covariates spring precipitation and spring precipitation squared greatly improved the model fit. We detected a short-lived increase in elk population growth rate following the 1988 drought and fires. Fertility and survivorship of adults appeared to have different density-dependant forms that together result in a biphasic relationship between population growth rate and density. This study confirms the presence of density-dependant regulation in the northern Yellowstone elk herd, and enhances our understanding of population dynamics of these ungulates. (Abstract by Taper as printed in Journal of Wildlife Management). (267)

Tyres, Dan. 1995. Winter ecology of moose on the Northern Yellowstone Winter Range. Yellowstone National Park, YCR.

Abstract in Progress (268)

VEGETATION

Bartos, D.L. and R.B. Campbell, Jr. 1998. Decline of quaking aspen in the Interior west: examples from Utah. Rangelands 20: 17-24.

The authors examine the aspen as a unique and vital tree to many interior-west ecosystems. They explore why aspen are in decline, namely suppression of fire and overgrazing, benefits of aspen stands, and what an ecosystem could experience after aspen decline. The authors' ideas are based largely on research done in Fishlake National Forest of southern Utah. This area historically held 75% aspen cover, but now holds only 20% aspen cover, 50% of that being currently endangered. Checking fire scars of ponderosa pine in the area, it was found that fires previously occurred on an average of every 19 years but have now been suppressed for over 150 years. Bartos and Campbell explore restoration efforts that have occurred in Fishlake National Forest and suggest them to other resources managers around the west along with details of which areas to consider priority and research topics to pursue. (272)

Bates, J., R.F. Miller, and T.J. Svejcar. 1998. Understory patterns in cut western juniper (Juniperus occidentalis spp. occidentalis Hook.) Woodlands. Great Basin Naturalist 58(4):363-374..

Western juniper (Juniperus occidentalis spp. Occidentalis) has rapidly expanded into shrub steppe communities in the Intermountain Northwest during the past 120 yr. Cutting juniper is a management tool used to restore shrub steppe communities. Response of the understory after cutting is strongly influenced by plant species composition existing prior to treatment. This study assessed distribution patterns of understory plants over 2 growing seasons after tree cutting in western juniper woodland. Cover, density, and diversity of understory species were compared among 3 locations: interspaces, duff zones (previously under tree canopies), and debris zones (beneath cut trees). Plant cover and density increased in all zones following tree cutting. Understory vegetation in cut woodlands exhibited strong zonal distribution. Cover and density of Poa sandbergii and Sitanion hystrix and canopy cover of annual forbs were greatest in duff zones ($P<0.05$). Density and cover of other perennial grasses and total densities of perennial forbs and annual forbs were greatest in interspaces ($P<0.05$). Debris zones tended to have the lowest overall understory cover and plant density values. Under juniper debris many species common to interspaces were reduced in density, although plants that survived or established beneath debris grew larger than their counterparts in interspaces. Species that increased in density and cover under debris were plants characteristic of duff zones and whose seeds are typically wind dispersed. (Abstract by Bates et al as printed in Great Basin Naturalist). (273)

Billings, W.D. (1989). Alpine Vegetation, in North American Terrestrial Vegetation, W.D. Billings and R.K. Peet, Editors. Paragon Books. p. 392-420.

Abstract in Progress (274)

Burke, I.C. W.A. Reiners, and R.K. Olson. 1989. topographic control of vegetation in a mountain big sagebrush steppe. Vegetation 84: 77-86.

Mountain big sagebrush steppes in Wyoming have strong spatial patterning associated with topography. We describe the spatial variability of vegetation in sagebrush steppe, and test that relationship between topography and vegetation using canonical correlation. Results of the analysis suggest that the main control over vegetation distribution in this system is wind exposure. Exposed sites are characterized by cushion plant communities and Artemisia nova, and less exposed sites by the taller sagebrush species Artemisia tridentata ssp. vaseyana. Topographic depressions and leeward slopes are characterized by aspen stands and nivation hollows. Measurements of soil microclimate suggest that a major influence of topographic position on vegetation is snow redistribution and its effect on soil moisture and temperature. (275)

Cook, J.G., T.J. Hershey, and L.L. Irwin. 1994. Vegetative response to burning on Wyoming mountain-shrub big game ranges. Journal of Range Management 47: 296-302.

Information on vegetative productivity and nutritive responses to burning in mesic, high elevation big sagebrush (Artemisia tridentata Nutt.) communities is limited. We investigated the effects of 2 wildfires and 3 prescribed fires on current year's production of herbs and selected shrubs for 3 years post-burn, and forage quality for 2 years post-burn in high elevation big sagebrush habitats in southcentral Wyoming. Production of perennial herbs on burned sites averaged twice that on controls, while production of annual herbs varied little 2-3 years post-burn. Burn-induced mortality of Saskatoon serviceberry (Amelanchier alnifolia (Nutt.) Nutt. Ex Roem.) was ?15%, but a 6-fold increase in twig production more that compensated for plant losses. Mortality of true mountain mahogany (Cercocarpus montanus Raf.) and antelope bitterbrush (Purshia tridentata (Pursh) DC) averaged 25% and 55%, respectively, but these losses generally were compensated by increases in browse production. Crude protein content of herbs from late spring through early fall was significantly higher on burns for 2 years post-burn. These results suggest well-managed prescribed burning programs gave potential to improve May through September diets of large herbivores in southcentral Wyoming mountain-shrub communities. (Abstract by Cook et al as printed in Journal of Range Management). (276)

Coughenour, M.B. and F.J. Singer. 1996. Herbaceous plant diversity responses to native ungulate herbivory on Yellowstone's northern winter range. Report. to U.S. National Biological Service.

Abstract in Progress (277)

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions of exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63-87.

Abstract in Progress (278)

Despain, D. G. . 1990. Yellowstone vegetation. Roberts Rinehart Publishers, Boulder, Colorado.

Abstract in Progress (604)

Despain, D. G. . 1995. Postfire plant regeneration and succession. Investigator's Annual Report.

Abstract in Progress (279)

Despain, D. G. . 1998. Bedrock-controlled vegetation patterns in the Greater Yellowstone geo-ecosystem. Pages 33 in No Editor/Author. Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts. Yellowstone Association, YNP

Soils in greater Yellowstone are largely derived from underlying bedrock. Bedrock pattern is determined by four tectonic episodes: Basin and range extension producing the mountain ranges in the northwest quadrant with mixtures of granite, sandstone, limestone and shales; two volcanic episodes, the andesitic Tertiary Absaroka volcanism and the rhyolitic Quaternary Yellowstone caldera in the central part; basement block uplift producing the Beartooth Range in the northeast and the Wind River Range in the southeast with large granitic cores and a fringe of mostly shale, limestone, and sandstone; and thrust faulting that produced repeating series of sandstone, shale and limestone in the mountain ranges of the southwest part of the ecosystem. Soils from sandstone, granite and rhyolite are sandy, poor in plant nutrients and hold little water. Shales, limestone, and andesites are high in nutrients and water holding capacity. Shale produces soils high in clay. Andesite and limestone can produce either course or fine soils. Alpine tundra covers areas above ca. 3000 m. Forests above 2600 m are dominated by Engelmann spruce, subalpine fir and white bark or limber pine. The courser limestones and andesites are covered by forests of Engelmann spruce and subalpine fir at elevations above 2200 m or Douglas-fir and limber pine down to 1800 m. Between 2200 and 2600 m lodgepole pine is dominant on the rhyolite, granite and sandstone and in the early successional stages on other forested substrates and higher elevations. Nonforested meadows, grasslands and sagebrush shrublands dominate finer soils derived from shales, lake sediments, loess deposits and some limestone and andesite. Grasslands above 1800 m are dominated by Idaho fescue and below by bluebunch wheatgrass. Dry shales below 1800 m usually support a desert vegetation. (Abstract by Despain. As printed in Making a place for nature, seeking our place in nature: 125th Anniversary Symposium; agenda and abstracts) (280)

Despain, D.G. 1973. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecological Monographs 43:32--355

The vegetation of the Big Horn Mountains is typical of the Central Rocky Mountain region; a lower Juniperus osteosperma zone is followed by Pinus ponderosa, Pseudotsuga menziesii, Pinus contorta, and Picea engelmannii-Abies lasiocarpa zones. Rock or geologic substrate type has a strong influence in forest vegetation. Sedimentary and granitic substrates are discussed, stating that most of the rainfall, less than 30 mm per month, is received during March, April, and May, making soil water relationships important. (281)

DeVelice, Robert L., Lesica, Peter=, Montana Natural Heritage Program. 1993. Plant Community Classification for Vegetation on BLM lands, Pryor Mountains, Carbon County, MT. Montana Natural Heritage Program, Helena, MT.

The Pryor Mountains provide desert like habitats unique in Montana and contribute significantly to the overall biological diversity of the state and the region. This study developed a classification of vegetation types on USDI BLM lands of the south Pryor Mountains, Carbon County, MT. Additionally, endemic and globally rare vegetation types were identified. Using a combination of two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DCA) 33 vegetation types were identified among the 197 study plots. Comparisons with a "comprehensive" listing of vegetation from the western United States revealed that 9 of the types from the Pryor Mountains had not been reported from elsewhere and 14 are rare globally. This concentration of rare vegetation types, in combination with previously documented occurrences of rare plant species, highlight the significant biodiversity values of the Pryor Mountains. (282)

Dinoor, A. and E. Eshed. 1984. The role and imprtance of pathogens in natural plant communities. Annual Review of Phytopathology 22: 443-466.

Abstract in Progress (283)

Emmerich, W.E. and R.K. Heitschmidt. 2001. Impacts of drought, grazing, and burning on rangeland stability. Soc. Range Manage. Abstr. Vol. 54, p. 38.

Drought, grazing, and burning all decrease standing biomass with the potential to influence rangeland productivity and stability through changes in surface runoff, erosion, and nutrient loss. Small increases for long periods can potentially lower rangeland ecosystem stability. The purpose of this work was to evaluate increases in runoff, erosion, and nutrient loss from drought, grazing, and burning and to calculate long term changes in nutrient status to address the issue of rangeland ecosystem stability. Drought and grazing were evaluated on the northern Great Plains under natural precipitation with non-weighing lysimeters, while prescribed burning was evaluated with rainfall simulation on southwestern Sonoran/Chihuahuan desert semiarid rangelands for changes in runoff, erosion, and nutrient loss. All the treatments increased runoff, erosion, and nutrient loss. The soil contained most of the nutrient and most of the lost nutrient was attached to sediment. Even at the accelerated soil loss rates, it would require many years of nutrient loss before it would effect ecosystem processes. Precipitation was found to replace some of the lost nutrient to sustain ecosystems stability. (Abstract by Emmerich and Heitschmidt. As printed in Society of Range Management abstracts) (284)

Evans, R.D.; Ehleringer, J.R. 1994. Water and nitrogen dynamics in an arid woodland. Oecologia. 99(3-4):233-242.

Arid environments are characterized by spatial and temporal variation in water and nitrogen availability. Differences in d15 N and dD of four co-occurring species reveal contrasting patterns of plant resource acquisition in response to this variation. Mineralization potential and nitrogen concentration of surface soils associated with plant canopies were greater than inter-canopy locations, and values decreased with increasing depth in both locations. Mineralization potential and nitrogen concentration were both negatively correlated with soil d15 N. The spatial variation in soil d15 N caused corresponding changes in plant d15 N such that plant d15 N values were negatively correlated with nitrogen concentration of surface soils. Plants occurring on soils with relatively high nitrogen concentrations had lower d15 N, and higher leaf nitrogen concentrations, than plants occurring on soils with relatively low nitrogen concentrations. Two general temporal patterns of water and nitrogen use were apparent. Three species (Juniperus, Pinus and Artemisia) relied on the episodic availability of water and nitrogen at the soil surface. d15 N values did no vary through the year, while xylem pressure potentials and stem-water dD values fluctuated with changes in soil moisture at the soil surface. IN contrast, Chrysothamnus switched to a more stable water and nitrogen source during drought. d15 N values of Chrysothamnus increased throughout the year, while xylem pressure potentials and stem-water dD values remained constant. The contrasting patterns of resource acquisition have important implications for community stability following disturbance. Disturbance can cause a decrease in nitrogen concentration at the soil surface, and so plants that rely on surface water and nitrogen may be more susceptible than those that switch to more stable water and nitrogen sources at depth during drought. (Abstract by Evans and Ehleringer as printed in Oecologia). (285)

Eversman, S. , Bennett, J. P. , Wetmore, C. M. , Glew, K. . 2002. Patterns of lichens diversity in Yellowstone National Park, Bryologist 105(1):27-42.

We here report 359 species in 103 genera from Yellowstone National Park. We found 71.3% of the total number of species in Picea engelmannii forests and 57.4% of the total number in Pseudotsuga menziesii stands. This compares to 42.3% of the species in Pinus contorta and 37.0% of the species in Pinus contorta/Pinus albicaulis stands. The presence of old Pseudotsuga menziessii and mature Picea engelmannii indicates that the forests have not burned for at least 300 yr, contributing to higher lichen diversity. The drier lodgepole pine and whitebark pine forests burn more frequently than every 300 yr and have fewer microhabitats for lichen growth. Species with thalli large enough to identify are beginning to recolonize substrates burned in the 1988 fires. Bryoria fremontii and Letharie vulpina exhibit levels of mercury and sulfur higher than those in other specimens in the region. Abstract by Eversman et al as printer in The Bryologist). (286)

Eversman, S. . 1998. Lichens of Grand Teton National Park. Pages 295-308 in Glenn, M. G., et al. Lichenographia Thomsoniana: North American lichenology in honor of John W. Thomson. Mycotaxon, Ltd, Ithaca, NY.

Two hundred twenty-one lichen species in 72 genera were identified from collections made in 1995 in Grand Teton National Park. Previous reports included four species not encountered in 1995. Nearly half the species (49%) were saxicolous, mostly on granitic substrates; 24% of the species were corticolous or lignicolous, 9% were terricolous, and the remaining species were on other substrates (decaying wood, plant debris, moss, litter, other lichens). Crustose species were 43% of the total number; 33% were foliose, 16% were fruticose, and 8% were squamulose. The lichen species and their distribution reflect the cold continental climate of the park, vegetation patterns, fire history, and perhaps human use of the valley part of the park. (Abstract by Eversman. As printed in Lichenographia Thomsoniana: North American lichenology in honor of John W. Thomson) (287)

Fahnestock, J.T., Detling, J.K. 1999. The influence of Herbivory on Plant Cover and Species Composition in the Pryor Mountain Wild Horse Range, USA. Plant Ecology. 144(2):312-320.

Effects of short-term and long-term ungulate grazing on plant species cover and composition in arid lowland and more mesic upland communities of the Pryor Mountain Wild Horse Range. (288)

Fisk, M.C., Schmidt Steven K., Timothy R. Seastedt. 1998. Topographic patterns of above- and belowground production and nitrogen cycling in alpine tundra. Ecology.79:7 p. 2253-2266.

Topography controls snowpack accumulation and hence growing-season length, soil water availability, and the distribution of plant communities in the Colorado Front Range alpine. Nutrient cycles in such an environment are likely to be regulated by interactions between topographically determined climate and plant species composition. We investigated variation in plant and soil components of internal N cycling across topographic gradients of dry, moist, and wet alpine tundra meadows at Niwot Ridge, Colorado. We expected that plant production and N cycling would increase from dry to wet alpine tundra meadows, but we hypothesized that variation in N turnover would span a proportionately greater range than productivity, because of feedbacks between plants and soil microbial processes that determine N availability. Plant production of foliage and roots increased over topographic sequences from 280 g?m-2?yr-1 in dry meadows to 600 g?m-2?yr-1 in wet meadows and was significantly correlated to soil moisture. Contrary to our expectation, plant N uptake for production increased to a lesser degree, from 3.9 g N?m-2?yr-1 in dry meadows to 6.8 g N?m-2?yr-1 in wet meadows. In all communities, the belowground component accounted for the majority of biomass, production, and N use for production. Allocation belowground also differed among communities, accounting for 70% of total production and 80% of N use for production in dry meadows compared to 55% of production and 65% of N use for production in moist meadows. Variation in microbial processes was highly related to soil moisture, and we found very consistent relationships among microbial respiration, gross N mineralization, and N immobilization among communities. These results indicate that the topographic soil moisture gradient is in fundamental control of the patterns of N turnover among communities and that differences in plant species do not appear to be as important. (Abstract by Fisk et al as printed in Ecology). (289)

Hadly-Barnosky, E.A. 1994. Grassland change over 2,000 years in Northern Yellowstone Park. Pp. 319 in plants and their environments: Proceedings of the First Biennial Scientific Conference on the Greater Yellowstone Ecosystem, D. Despain ed. Tech. Rep, NPS/NRYELL/NRTR, denver, CO: U.S. Department of the Interior, National Park Service, Natural Resources Publication Office.

Plant communities of the northern range in Yellowstone Park are composed of a patchwork of microhabitats locally governed by a variety of environmental factors including slope, aspect, substrate, effective moisture, and soil type, to name a few. Along the Lamar River, upstream of its confluence with the Yellowstone River, microhabitat ecotones are especially pronounced along moisture gradients. The majority of the large till-covered surface above the river is sparsely vegetated with grassy patches and sagebrush (Artemisia). Mesic sites with denser grass are found in small swales and drainages. North-facing slopes are covered with Douglas fir (Pseudotsuga menziesii) forest. (Abstract by Hadley-Barnosky as printed in Plants and their environments: proceedings of the first biennial scientific conference on the Greater Yellowstone Ecosystem). Evidence from a paleontological site, Lamar Cave, suggests that the spatial coverage of these and other microhabitats has changed during the past 1,700 years. At least 1,500 years ago the prairie vole (Pitymys ochrogaster) occupied the study area, as did the western jumping mouse (Zapus princeps). Neither now occupies the study area, and both are tall-grass inhabitants today. Also at 1,500 years ago, relative percentages of small mammals [voles (Microtus) that dwell in mesic microhabitats today were prevalent over those that favor open, xeric grasslands [ground squirrels (Spermophilus)]. By 1,000 years ago, this condition was reversed, with ground squirrels dominating the faunal assemblage at the cave and the prairie vole and jumping mouse absent from the record. Slightly more mesic conditions gave returned since 1,000 years ago, as evidenced by a slight rise in vole percentages relative to ground squirrels; however, the present is still drier than the mesic condition of 1,500 years ago. This evidence from the small mammal fossils of Lamar Cave indicates that grass density has changes over 2,000 years and suggests that microhabitats expand and contract with changing environmental conditions, in this case probably effective moisture. (290)

Heidel, Bonnie, Fertig, Walter. 2001. Vascular Plant Species Checklist of Bighorn Canyon National Recreation Area (Montana and Wyoming). Wyoming Natural Diversity Database, Laramie, WY.

2001 Vascular Plant Checklist of Bighorn Canyon National Recreation Area, Montana and Wyoming. Prepared for National Park Service-Bighorn Canyon National Recreation Area and the Greater Yellowstone Network. (292)

Johnson, P. L. and W. D. Billings. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. Ecological Monographs 32: 105-135.

Abstract in Progress (293)

Kay, C. E. , Wagner, F. H. . 1994. Historic condition of woody vegetation on Yellowstone's northern range: a critical test of the "natural regulation" paradigm. Pages 151-169 in Despain, D. G. . Plants and their Environments: proceedings of the First Biennial Scientific Conference on the Greater Yellowstone ecosystem, Sept 16-17, 1991, Mammoth Hot Springs Hotel. Natural Resources Publication Office, Denver, Colorado.

The Park Service's "natural regulation experiment" is predicated on the assumption that large numbers of elk (12,000-15,000) have wintered on Yellowstone's northern range for the last several thousand years. Agency biologists believe that the park's vegetation coevolved with these herbivores and reached equilibrium conditions, which they term "ecological carrying capacity." According to this model, elk influences on the vegetation are "natural" and represent the "pristine" condition of the park. If this paradigm is correct, early historic photographs of woody vegetation should show that aspen, willows, and conifers were as heavily browsed or highlined by ungulates in the early years of the park's existence as they are today, and aspen stem damage by elk was the norm then as it is now. To evaluate these predictions and to test the "natural regulation" paradigm, we reviewed approximately 50,000 early images taken in the park. Photos of aspen stands on the park's northern range taken during the 1880's and 1890's do not show any evidence of elk-induced bark damage. Photos of aspen, willows, and conifers taken from 1872 to the 1890's do not show evidence of ungulate browsing or highlining. Some early photos do show occasional conifers that lacked their lower branches, but evidence indicates that this was caused by light groundfires burning or killing the lower branches and by human removal of branches. Previous authors apparently confused fire and human highlining with that caused by ungulates.

Conifers and other woody vegetation in these 1870-1890 images were approximately 70-100 years old or older when they were photographed. Since they show no evidence of ungulate use, this suggests that few, if any, elk wintered in Yellowstone from the late 1700s through the 1870s. Thus, ungulate highlining of conifers and repeated browsing of other woody vegetation are not "natural" and represent a departure from conditions that existed before the establishment of Yellowstone National Park. These photographs do not support the Park Service's contention that Yellowstone was always a major elk wintering area and that the northern herd did not increase and alter the vegetation. Since these data do not support one of the key assumptions upon which "natural regulation" is based, that paradigm must be rejected. (Absract by Kay and Wagner as printed in Plants and their Environments: Proceedings of the First Biennial Scientific Conference on the Greater Yellowstone ecosystem). (294)

Knight, D.H., G.P. Jones, Y. Akashi, and R.W. Myers. 1987. Vegetation ecology in the Bighorn Canyon National Recreation Area. Final Rept. To U.S. Natl. Pk. Serv. And Univ. of WY, Natl. Pk. Serv. Res. Ctr. Dept. Botany, Univ. of WY, Laramie. 114 pp.

The ecology of terrestrial vegetation in the Bighorn Canyon National Recreation Area (BCNRA) was studied during the period 1984-1986. Seventy-five stands, distributed throughout the BCNRA, were sampled for plant species cover and various environmental characteristics. A vegetation classification and map were developed, the data were analyzed using gradient analysis techniques, and the results were synthesized with those from other relevant studies in the region. In general, the vegetation of the BCNRA is 40% juniper/curlleaf mountain mahogany woodland, 16% riparian vegetation, 15% desert shrubland, 12% sagebrush steppe, 8% grassland, 6% coniferous woodland, 2% agricultural land, 1% marsh, and 0.1% Great Plains shrubland. Some of these general vegetation types were sub-divided, creating 21 types that are included on the black-and-white, 1:24,000 map. All types except marshes and agricultural land are discussed in this report, with the discussion focusing on adaptations of the dominant plant species, environmental factors affecting the distribution of each vegetation type, vegetation changes that have occurred and can be expected to occur in the future, certain aspects of weed ecology, and characteristics of the vegetation mosaic along the north-south axis of the Recreation Area. The riparian vegetation appears to be changing most rapidly, due in large part to flood control on the Shoshone and Bighorn Rivers. The suppression of fires and floods, combined with grazing and the creation of mudflats by fluctuating Bighorn Lake water levels, have produced ideal conditions in the riparian zone for the invasion of various exotic plants, saltcedar in particular. The report concludes with a section on using vegetation data to facilitate management activities. (Abstract by Knight et al as printed in the Final Report to U.S. National Park Service and the University of Wyoming). (295)

Lesica, Peter and Achuff, Peter, Mapping the distribution of Rare plants and plant communities for reserve design in Pryor Mountain Desert, Carbon County, Montana, 1992. Northwest Environmental Journal 8(1):179-181.

This report is the summary of the study which focused on 35 species of vascular plants listed as species of special concern or of limited distribution by the Montana Natural Heritage Program. Locations were mapped, population density estimated, and soil and vegetation information was recorded for each population observed. (296)

Merrill, E. H. , Stanton, N. L. , Hak, J. C. . 1996. Responses of bluebunch wheatgrass, Idaho fescue, and nematodes to ungulate grazing in Yellowstone National Park. Pages 73-84 in Singer, F. J. . Effects of grazing by wild ungulates in Yellowstone National Park. U. S. Department of the Interior, National Park Service, Denver CO

We sampled above and belowground biomass of Idaho fescue (Festuca idahoensis) bluebunch wheatgrass (Agropyron spicatum) plants and nematode densities under these species inside and outside a 2-year old exclosure on the northern range of Yellowstone National Park in May through September, 1990. Native ungulates grazed the site primarily in winter and early spring. Grazing during this period removed essentially all the standing dead plant material. In early May, green biomass of plants of both species outside the exclosure was significantly lower than plants in the exclosure but off-take by ungulates accounted for only 18-51% of this initial difference. Indirect effects of grazing, such as the effects of removing standing dead material on microclimatic conditions, likely influenced early growth. By the end of the growing season, both species had similar biomass to ungrazed plants despite an increase in root-feeding nematodes early in the growing season. Lower root biomass, higher densities of bacteria-feeding nematodes (no./g root biomass), and higher concentrations in foliar nitrogen (N) with grazing suggested that root mortality, due to spring grazing, provided a short-term source of carbon for microbial activity and that microbial-feeding nematodes increased the turnover rates of microbial bound N. Densities (no./g root biomass) of root-feeding nematodes increased rather than decreased with grazing. Because N concentration of roots did not differ between grazed and ungrazed plants, we suggest that there was a reduction in secondary chemicals or an increase in root hairs, which are preferred sites for nematode feeding. (Abstract by Merrill et al as printed in Effects of grazing by wild ungulates in Yellowstone National Park). (298)

Mueggler, W.F. 1988. Aspen Community types of the Intermountain Region. Gen. tech. Rep. INT250. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

This vegetation classification is based upon existing community structure and composition in the aspen-dominated forest of the Intermountain Region of the Forest Service. The 56 community types occur within eight tree-cover types. A diagnostic key using indicator species facilitates field identification of the community types. Vegetational composition, productivity, and successional status are included. Tables provide detailed comparisons of community types. The classification and description are based upon field data from over 2,100 aspen stands scattered over southeastern Idaho, western Wyoming, Utah, and Nevada. (Abstract by Mueller as printed in GTR-INT-250). (299)

Mullenders, W. , Coremans, M. . 1996. Modern pollen spectra from Yellowstone National Park, Grand Teton National Park, Wind River Range and adjacent regions, Wyoming. Pages 1-44 in Gullentops, F. Pleistocene Palynostratigraphy. Edition Peeters, Leuven, Belgium.

More than 200 surface samples were collected for comparison between modern pollen spectra and present vegetation as an aid to interpretation of fossil pollen diagrams. The modern samples do not reproduce exactly the surrounding vegetation. (300)

No Editor/Author. Plants and their Environments: First Biennial Scientific Conference on the Greater Yellowstone ecosystem, Sept 16-17, 1991, Mammoth Hot Springs Hotel; agenda and abstracts.

Abstract in Progress (301)

O'Brien, E. M., Field, R. and Whittaker, R. J. (2000) Climatic gradients in woody plant (tree and shrub) diversity: water-energy dynamics, residual variation, and topography. Oikos, v. 89 pp 588-600.

Recent studies at the macro-scale have demonstrated that geographic gradients in the richness of plants, in particular of woody plants, such as trees and shrubs, can be viewed as by-products of water-energy dynamics. According to this view, they are climatic rather than latitudinal/longitudinal gradients, relating to coincident and predictable variation in planetary surface-atmosphere thermal dynamics and consequent patterns in biological activity. Previous analyses have shown that a two-variable model capturing the dynamic relationship between energy (heat/light) and water (rainfall) accounts for most of the variation in woody plant richness across southern Africa at species, genus, and family levels. Here we move towards a more

complete explanation, while demonstrating how geographic analysis of residuals can be used to identify the type and sequence of additional variables for inclusion, either at the same or at more discrete scales of analysis. Residual geographic variation in richness from the two-variable model displays a geographic pattern unrelated to longitude and latitude. Regional clusters of under- and over-prediction point to macro-scale variation in topographic relief as a significant. When topographic is added as a third variable, the explanatory power (R2) increases by 7 to 12%, and the subsequent pattern of variation in residuals becomes even more unpredictable. What clustering remains points to other macro-, and meso- or micro-scale variables that need to be considered. Such a top-down, trans-scalar approach permits systematic and objective development of more complete explanations, while the three-variable macro-scale model developed herein is the basis for a powerful research tool for ecologists, biogeographers, conservationists and bio-climatologists alike. (Abstract by O'Brien et al as printed in Oikos). (302)

Patten, D.T. 1969. Succession from sagebrush to mixed conifer forest in the Northern Rocky Mountains. Am. Mid. Nat. 82: 229-240.

In northwestern Yellowstone National Park, lodgepole pine is invading sagebrush areas. The vegetational composition and environment of sagebrush, lodgepole pine, and intermediate sites were studied. Young lodgepole pine had little influence on the environment or vegetational composition of the sagebrush; however, when lodgepole pine was mature the shade-intolerant species, including sagebrush, were eliminated and shade-tolerant species developed. In the mixed conifer forest the environment was suitable for further development of climax conifers. Thus, lodgepole pine is not only a fire-successional species but part of a normal climatically caused sere originating with vegetation dominated by big sagebrush. (Abstract by Patten as printed in The American Midland Naturalist). (304)

Patten, R.S., Knight, D.H. 1994. Snow avalanches and vegetation pattern in Cascade Canyon, Grand Teton National Park, Wyoming, USA. Arctic Alpine Research. 26 1: 35-41.

Snow avalanches in Cascade Canyon, Grand Teton National Park, have a significant effect on the region's vegetation mosaic, increasing the area's community diversity and creating a fragmented vegetation pattern. The structure and persistence of communities within avalanche tracks is a function of the frequency of avalanche occurrence. In many areas, shrub cover and conifer density increase as avalanche frequency increases. Conifers decrease in size yet increase in age as avalanches occur more often, a consequence of slower growth rates in trees within avalanche tracks. Because the probability of avalanche damage to conifers is related to the size of the tree, slow growth rates result in small trees that can survive many years in avalanche tracks, contributing to the persistence of the avalanche community. The canyon's vegetation patterns appear fairly stable due to the spatial and temporal consistency of avalanche occurrence and the persistence of communities in avalanche tracks. The primary effect avalanches have on this landscape is to increase the fragmentation of the vegetation patterns rather than to drive dynamic changes in the landscape mosaic. (305)

Peet, Robert K. 2000. Forests and meadows of the Rocky Mountains. Chapter 3 in: Barbour, M. G. and W. D. Billings (editors). North American Terrestrial Vegetation. Second Edition. Cambridge University Press. (Gives a very good description of the context for the vegetation of the parks.)

Abstract in Progress (306)

Perryman, B.L., A.M. Maier, A.L. Hild, and R.A. Olson. 2001. Demographic characteristics of 3 Artemisia tridentata Nutt. subspecies. J. Range Manage. 54:2 p.166-170.

Previous research suggested that woody plant recruitment may occur in pulses on semi-arid areas. The overall objective of this study was to determine if this pulse phenomena was recorded in the demographic structures of big sagebrush (Artemisia tridentata Nutt.) stands in Wyoming. In 1997, approximately 75 stem cross sections were collected from 9 stands of each of 3 subspecies of big sagebrush in Wyoming along elevation and climatic gradients. Annual growth-rings were used to identify year of establishment and demographic characteristics were analyzed from age-class frequencies. Mean stand ages of the 3 subspecies were different (P=0.002), and analyses revealed that Wyoming (A. tridentata spp. wyomingensis) and mountain big sagebrush (A. tridentata spp. vaseyana) stand ages (32 ? 9 and 26 ? 9 years, respectively) were significantly older than basin big sagebrush (A. tridentata spp. tridentata) (17 ? 3) stands (P < 0.05). Mean recruitment intervals (years) were shorter for basin (1.6) than for Wyoming (2.3) and mountain (2.2) sagebrush (P=0.01). The number of cohorts did not differ among the subspecies (P=0.11), but the percent of years with recruitment was significantly higher for basin (59%) compared to Wyoming (37%) and mountain (39%) subspecies (P<0.0001). Age-class frequency distributions of each stand and regional stand combination were assessed for dispersion across each associated period of record. Chi-square goodness-of-fit tests were performed for the negative binomial distribution. All stands (with one exception) and all 3 regional stand combinations fir the negative binomial distribution. Age-class frequency patterns indicate that recruitment is clustered or aggregated across each period of record. Recruitment in big sagebrush stands occurs in pulses throughout Wyoming. (Abstract by Perryman et al as printed in Journal of Range Management). (307)

Piennetti, R. R. Menezes, M. Coughenour. 2001. Changes induced by elk browsing on willow (Salix monticola) woody biomass, production and distribution,; its relationship with plant water, carbon, and nitrogen dynamics. Oecologia. 127(3):334-342.

Willows are dominant woody plants of many high elevation riparian areas of the western USA, and constitute an important food resource for various ungulates, which tend to concentrate in riparian areas. The response of willow to browsing was analyzed in the elk winter range of Rocky Mountain National Park, by considering the effect of elk browsing on Salix monticola Bebb, one of the most common willow species in this area. Unbrowsed and browsed treatments were established during the 1997 growing season (May to October), using eight long-term exclosures built in the fall of 1994. Plants in the browsed treatment were in the areas open to browsing, but they were protected from browsing by small exclosures during the experimental period. Winter browsing by elk induced the following measured responses in plant morphology and development: (1) higher shoot biomass production but similar leaf biomass and leaf area per plant, (2) a lower number of and bigger shoots, (3) a lower number of and bigger leaves, and (4) flower inhibition. In addition, we infer that browsing induces (5) lower belowground allocation and (6) a more negative N balance but a higher soil N uptake. We conclude that elk browsing negatively effects willow even though willow compensate for above ground biomass removal. Continuous browsing produces long-term changes in willow morphology which constrain plant growth and development. High browsing utilization, as occurred in this experiment, could therefore reduce the competitive ability and survivorship of willow, in particular under drier environmental conditions. (Abstract by Peinetti et al as printed in Oecologia). (308)

Pyke, D.A., J.E. Herrick, P. Shaver, and M. Pellant. 2002. Rangeland health attributes and indicators for qualitative assessment. Journal of Range Management 55

Panels of experts from the Society for Range Management and the National Research Council proposed that status of rangeland ecosystems could be ascertained by evaluating an ecological site's potential to conserve soil resources and by a series of indicators for ecosystem processes and site stability. Using these recommendations as a starting point, we developed a rapid, qualitative method for assessing a moment-in-time status of rangelands. Evaluators rate 17 indicators to assess 3 ecosystem attributes (soil and site stability, hydrologic function, and biotic integrity) for a given location. Indicators include rills, water flow patterns, pedestals and terracettes, bare ground, gullies, wind scour and depositional areas, litter movement, soil resistance to erosion, soil surface loss or degradation, plant composition relative to infiltration, soil compaction, plant functional/structural groups, plant mortality, litter amount, annual production, invasive plants, and reproductive capability. In this paper, we detail the development and evolution of the technique and introduce a modified ecological reference worksheet that documents the expected presence and amount of each indicator on the ecological site. In addition, we review the intended applications for this technique and clarify the differences between assessment and monitoring that lead us to recommend this technique be used for moment-in-time assessments and not be used for temporal monitoring of rangeland status. Lastly, we propose a mechanism for adapting and modifying this technique to reflect improvements in understanding of ecosystem processes. We support the need for quantitative measures for monitoring rangeland health and propose some measures that we believe may address some of the 17 indicators. (Abstract by Pyke as printed in Journal of Range Management). (309)

Romme, W. H. , Turner, M. G. , Wallace, L. L. , Walker, J. S. 1995. Aspen, elk, and fire in northern Yellowstone National Park. Ecology. 76 7: 2097-2106.

Most stands of trembling aspen (Populus tremuloides) in northern Yellowstone National Park appear to have become established between 1870 and 1890, with little regeneration since 1900. There has been controversy throughout this century regarding the relative roles of browsing by elk (Cervus elaphus) and fire suppression in preventing aspen regeneration. Fires in 1988 burned 22% of the northern ungulate winter range in the park, and created an unusual opportunity to investigate interactions between fire, ungulate browsing, and aspen regeneration. We tested two hypotheses. (1) The fires would stimulate such prolific sprouting of new aspen stems in burned stands that many stems would escape ungulate browsing and regenerate a canopy of large aspen stems. (2) Browsing pressure would be so intense that it would inhibit aspen canopy regeneration in the burned stands, despite prolific sprouting, but increased forage production in the burned areas would attract elk so that they would not seek out remote aspen stands, and hence, aspen regeneration would occur in unburned aspen stands remote from the burned areas. We sampled aspen sprout density, height, growth form, and browsing intensity in six burned aspen stands, six unburned stands close (lt 1 km) to the burned area, and six unburned stands remote (gt 4 km) from the burned area. Density of sprouts was generally greater in the burned stands than in the unburned stands in spring 1990 (2 yr after the fires), but was approaching the density of unburned stands by fall 1991. There were no significant differences in browsing intensity (percent of aspen sprouts browsed by ungulates) in 1990 or 1991 among burned, unburned close, or unburned remote stands, nor were there differences in relation to growth form (juvenile vs. adult sprouts). Unbrowsed sprouts generally were lower than the depth of the snowpack, suggesting that elk browsed nearly all sprouts that were accessible. The age distribution of 15 aspen stands across the northern winter range indicated that regeneration of large canopy stems had been episodic even prior to the establishment of the park in 1872. The period 1870-1890, when the present-day aspen stands were generated, was historically unique: numbers of elk and other browsers were low, climate was relatively wet, extensive fires had recently occurred, and large mammalian predators of elk (e.g., wolf, Canis lupus) were present. This combination of events has not recurred since 1900. The recent paucity of aspen regeneration in northern Yellowstone National Park cannot be explained by any single factor (e.g., excessive elk numbers or fire suppression) but involves a complex interaction among factors. (310)

Roundy, B.A., J.A. Young and R.A. Evans. 1981. Phenology of salt rabbitbrush (Chrysothamnus nauseosus ssp. consimilis) and greasewood (Sarcobatus vermiculatus). Weed Sci. 29:448-454.

Salt rabbitbrush [Chrysothamnus nauseosus (Pallas) Britt., ssp. consimilis (Greene)] and greasewood [Sarcobatus vermiculatus (Hook.) Torr.] grow slowly in early spring until mid to late May. They then begin a period of rapid growth, at which time susceptibility to foliar herbicides is probably greatest. Greasewood ceases rapid growth in mid June to early July, but salt rabbitbrush continues to grow rapidly until early August. Greasewood that resprouts after herbicide application has a longer rapid-growth period than shrubs in an untreated stand. An average leader length of 4 cm indicates that rapid growth of salt rabbitbrush is underway, and first opening of the flower buds indicates that rapid growth is over. Appearance of greasewood staminate spikes indicates that rapid growth has begun, and the first appearance of dried spikes indicates that growth has ceased. Simultaneous control of these shrubs with a single application of phenoxy herbicides may only be possible during the relatively short period when both are growing rapidly. This period may only occur from late May to mid June in some stands and years, but may occur from mid may to early July in other cases. (311)

Schimel, D.S., W.J. Parton, T.G.F. Kittel, D.S. Ojima, and C.V. Cole. 1990. Grassland biogeochemistry: Links to atmospheric processes. Climatic Change 17:13-25. [ISI citation index = 79]

Regional modeling is an essential step in scaling plot measurements of biogeochemical cycling to global scales for use in coupled atmosphere-biosphere studies. We present a model of carbon and nitrogen biogeochemistry for the U.S. Central Grasslands region based on laboratory, field, and modeling studies. Model simulations of the geography of C and N biogeochemistry adequately fit observed data. Model results show geographic patterns of cycling rates and element storage to be a complex function of the interaction of climatic and soil properties. The model also includes regional trace gas simulation, providing a link between studies of atmospheric geochemistry and ecosystem function. The model simulates nitrogenous trace gas emission rates as a function of N turnover and indicates that they are variable across the grasslands. We studied effects of changing climate using information from a global climate model. Simulations showed that increases in temperature and associated change sin precipitation caused increases in decomposition and long-term emission of CO_2 from grassland soils. Nutrient release associated with the loss of soil organic matter caused increases in net primary production, demonstrating that nutrient interactions are a major control over vegetation response to climate change. (Abstract by Shimel et al as printed in Climatic Change). (312)

Shaw, Richard J. 1992. Vascular plants of Grand Teton National Park and Teton County. Grand Teton Natural History Association, Salt Lake City, UT.

This checklist was assembled for several reasons: (1) my Field Guide to the Vascular Plants of Grand Teton National Park and Teton County, Wyoming which appeared in 1976 has long been out of print; (2) over 125 additional species have been found in the park and county that were not recoginzed in 1976; (3) tremendous changes have occurred in roads and trails within the park in the last sixteen years as well as a startling increase in the population in the county; (4) a list is needed which summarizes the known information of the flora for visitors, students and vegetation mangers. (314)

Singer, F. J. , Harter, M. K. 1991. Effects of long-term protection from elk grazing on bunchgrass and big sagebrush communities on Yellowstone's winter range. Pages 34-35 in No Editor/Author. Plants and their Environments: First Biennial Scientific Conference on the Greater Yellowstone ecosystem, Sept 16-17, 1991, Mammoth Hot Springs Hotel; agenda and abstracts.

The effects of long term protection of plant communities form elk grazing were studied at 8 large (2 ha) enclosures constructed in 1985 and 1962. Shrub transects were read at approximately 5-year intervals during the 1958-1990 period. Grassland measures were taken inside of and in adjacent grazed sites in 1986-1987 at all of the enclosures and during four of the years, 1986-1990, at the Blacktail Deer Creek enclosures.

Winter grazing by elk resulted in less standing crop biomass of grasses only in 1986, following a drier than normal spring. Total grasses were not influenced by grazing in any other year, and total forbs were not influenced by grazing in any year ($P>0.05$). Biomass of two grasses, June grass (Koeleria cristata) and thick spiked wheatgrass (Agropyron spicatum), were more abundant on grazed sites, while only one grass, Poa sandberghi, and 2 nongrasses, Artemesia frigida and Phlox hoodii, were less abundant on grazed sites ($P < 0.05$). Morphological characteristics were not influenced by grazing, with the exception that vegetative culms of grasses were shorter on grazed sites. There was one-quarter the litter and one-third more bare ground on grazed sites. Grazing enhanced the protein content of common grasses 10-36 %, but grazing did not significantly influence the digestibility of grasses. Protein content varied 8-20% between years. Grazing slightly enhanced other nutrients (Ca, Mg, K) in Idaho fescue (Festuca idahoensis) ($P < 0.05$), but not in junegrass or bluebunch wheatgrass (A. spicatum). Heights of seed stalks of bluebunch wheatgrass were shorter in 1986 than in the other three years, further suggesting that the growing conditions in 1986 were less than optimum. Seed heights are often used as an indicator of grass vigor. About 16% more grass biomass was produced under big sage cover than in open bunchgrass communities. Soil moisture was not influenced by grazing, and soil moisture did not vary between sage and open grass stands.

Protection from ungulates benefited big sagebrush growth and reproduction at the lower enclosures near Gardiner. Pronghorns (Antilocapra Americana) and mule deer (Odocoileus hemionus) also winter in this area and the big sage subspecies involved is the more palatable Artemesia tridentate Wyomingensis, or Wyoming big sage. Numbers of big sage increased 348% and cover increased 828% inside the enclosures, 1958-1962, while numbers of big sage declined 40% and cover declined 29% on grazed sites.

Big sage trends were similar on grazed and protected sites at the remaining higher elevation enclosures. Numbers of big sage declined an average of 20% on both grazed and protected sites, but the big sage individuals were taller and larger, 1958-1990. Big sage canopy volumes increased 440% on protected sites and increased 210% on grazed sites. Only elk and bison (Bison bison) winter at the higher sites; they eat less big sage, and the big sage subspecies are the less palatable Basin and Mountain big sage (A. t. triaentata and A. t. vaseyana). All shrubs, except common rabbitbrush (Chrysothamnus nauseosus), were shorter and smaller in volume on grazed sites. Big sage averaged 16% taller on protected sites, horsebrush (Tetradeymia canescens) was 91% taller and green rabbitbrush (C. viscidiflorus) was 42% taller. Common rabbitbrush individuals were 36% taller and crown volumes were 200% larger on grazed sites. Shrub seedling reproduction was more common and age class distributions were younger on grazed sites. Apparently either the reduction in competition through reduced shrub size or trampling by ungulates enhanced shrub establishment on grazed sites. Abstract by Singer and Harter. As printed in Plants and their Environments: First Biennial Scientific Conference on the Greater Yellowstone ecosystem.) (315)

Spence, John R. 1980. Vegetation of subalpine moraines in the Teton Range, Grand Teton National Park, Wyoming. Utah State University, Logan, UT.

This study attempts to characterize the environment and plants that are found growing on the neoglacial moraines and other glacial deposits of neoglacial age in front of the glaciers in the Teton Range, located in Grand Teton National Park, Wyoming. (316)

Sprugel, D. G. 1991. Disturbance, equilibrium, and environmental variability: What is "natural" vegetation in a changing environment?. Biological Conservation. 58 1: 1-18.

To most early ecologists, the "natural" ecosystem was the community that would be reached after a long period without large-scale disturbance (fire, windstorm, etc.). More recently, it has been realized that in most areas some type of large-scale disturbance is indigenous, and must be included in any realistic definition of "naturalness". In some areas an equilibrium may exist in which patchy disturbance is balanced by regrowth, but in others equilibrium may be impossible because (1) individual disturbances are too large or infrequent; (2) ephemeral events have long-lasting disruptive effects; and/or (3) climate changes interrupt any movement toward equilibrium that does occur. Examples of non- equilibrium ecosystems include the African savannas, the Big Woods of Minnesota, the lodgepole pine forests of Yellowstone National Park, and possibly the old-growth Douglas-fir forests of the Pacific Northwest. (317)

Stohlgren, T. J., M. B. Coughenour, G. W. Chong, D. Binkley, M. A. Kalkhan, L. D. Schell, D. J. Buckley, and J. K. Berry. 1997. Landscape analysis of plant diversity. Landscape Ecology. 12:3 p.155-170.

Studies to identify gaps in the protection of habitat for species of concern have been inconclusive and hampered by single-scale or poor multi-scale sampling methods, large minimum mapping units (MMU's of 2 ha to 100 ha), limited and subjectively selected field observations, and poor mathematical and ecological models. We overcome these obstacles with improved multi-scale sampling techniques, smaller MMU's (< 0.02 ha), an unbiased sampling design based on double sampling, improved mathematical models including species-area curves corrected for habitat heterogeneity, and geographic information system-based ecological models.

We apply this landscape analysis approach to address resource issues in Rocky Mountain National Park, Colorado. Specifically, we quantify the effects of elk grazing on plant diversity, identify areas of high or unique plant diversity needing increased protection, and evaluate the patterns of non-native plant species on the landscape. Double sampling techniques use satellite imagery, aerial photography, and field data to stratify homogeneous and heterogeneous units and “keystone ecosystems’’ (ecosystems that contain or support a high number of species or have distinctive species compositions). We show how a multi-scale vegetation sampling design, species-area curves, analyses of within- and between-vegetation type species overlap, and geographic information system (GIS) models can be used to quantify landscape-scale patterns of vascular plant diversity in the Park. The new multi-scale vegetation plot techniques quickly differentiated plant species differences in paired study sites. Three plots in the Ouzel Burn area (burned in 1978) contained 75 plant species, while only 17 plant species were found in paired plots outside the burn. Riparian areas contained 109 plant species, compared to just 55 species in paired plots in adjacent forests. However, plant species richness patterns inside and outside elk exclosures were more complex. One elk exclosure contained more species than its adjacent open range (52 species inside and 48 species outside). Two elk exclosures contained fewer species inside than outside (105 and 41 species inside and 112 and 74 species outside, respectively). However, there was only 26% to 48% overlap (using Jaccard’s Coefficient) of plant species composition inside and outside the exclosures. One elk exclosure had 13% cover of non-indigenous species inside the exclosure compared to 4% outside, but non-indigenous species cover varied by location. We compared plant diversity patterns from vegetation maps made with 100 ha, 50 ha, 2 ha, and 0.02 ha MMU’s in the 754 ha Beaver Meadows study area using four 0.025 ha and twenty-one 0.1 ha multi-scale vegetation plots. Preliminary data suggested that the 2 ha MMU provided an accurate estimate of the number of plant species (–14%) for a study area, but the number of habitats (polygons) was reduced by 67%, and aspen, a unique and important habitat type, was missed entirely. We describe a hypothesis-driven approach to the design and implementation of geospatial databases for local resource monitoring and ecosystem management. (Abstract by Stohlgren et al as printed in Landscape Ecology). (318)

Tinker, D. B. , et al. 1994. Landscape-scale heterogeneity in lodgepole pine serotiny. Canadian Journal of Forest Research. 24 5: 897-903.

A 1992 study of serotiny in lodgepole pine (Pinus contorta Dougl. ex Loud. var. latifolia Engelm.) in Yellowstone National Park asked four questions: (i) are there morphological characteristics that can be used to estimate prefire proportion of serotinous trees in forests that burned in 1988?; (ii) at what spatial scale does percent serotinous trees vary across the landscape?; (iii) which environmental factors are correlated with serotiny?; and (iv) what is the relationship between prefire serotiny and postfire lodgepole pine seedling density? We first sampled cone characteristics in serotinous and nonserotinous trees along four 2950-m transects in unburned forests, and examined burned trees nearby. Results indicated that asymmetrical cones and an acute angle of cone attachment to the branch were reliable indicators of serotiny even in burned trees. We then sampled nine patches of lodgepole pine forest that had burned in 1988, and varied in size from 1-3600 ha. We sampled serotiny at varying intervals along two perpendicular transects that crossed in the center of each patch. At each sample point, the 12 nearest canopy lodgepole pines were classified as serotinous or nonserotinous. We concluded that the percentage of serotinous trees is most variable at intermediate scales of 1-10 km, and is relatively homogeneous at both fine scales (lt 1 km) and at very broad scales (tens of kilometers). Percent serotiny was generally more variable and greater at low to middle elevations. Prefire density of serotinous trees was a more important predictor of postfire seedling density than aspect, slope, or soil type. These findings have important implications for landscape-level patterns in postfire regeneration of lodgepole pine. (319)

Wambolt, C. L. , Sherwood, H. W. . 1999. Sagebrush response to ungulate browsing in Yellowstone. Journal of Range Management. 52 4: 363-369.

"Big sagebrush (Artemisia tridentata) has decreased as a result of ungulate (Odocoileus hemionus hemionus, Antilocapra americana americana and Cervus elaphus nelsoni) browsing during the first half of the twentieth century on the Northern Yellowstone Winter Range, Wyoming, USA. The shrub characteristics of Northern Yellowstone Winter Range sagebrush habitat types continually browsed were compared with those protected for 32-37 years. Measurements were taken in and out of exclosures for 19 environmentally paired, protected, and browsed sites. There were significant differences in development between protected and browsed shrubs. Big sagebrush canopy cover at the 19 sites averaged 19.7% with protection and 6.5% where browsed and plants were twice as numerous under protection. Winter forage production of individual big sagebrush plants was also greater under protection at 16 of the 19 paired sites. Subdominant sprouting shrubs generally responded the same as big sagebrush." (320)

West, Neil E. 1994. Effects of fire on salt-desert shrub rangelands. In: Monson, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings-ecology and management of annual rangelands; 1992 May 18-21; Boise, ID. Gen. Tech. Rep. INT-GTR-313.Ogden, UT: U.S.

Fire was not thought to be a driving variable in slat-desert shrub ecosystems prior to 1983. The El Nino related extreme wetness of 1983-85 resulted in a profusion of mostly exotic annuals followed by wildfires. Unfortunately, the most productive sites, near the upper boundary of the type, have been most often affected. Major species such as shadscale (Atriplex confertifolia) and budsage (Artemisia spinescens) do not resprout following fire. Winter fat (Ceratoides lanata), saltbush (Atriplex nuttallii), gray molly (Kochia americana) and black greasewood (Sacrobatus vermiculatus) do resprout, but subsequent populations appear reduced. (Abstract by West as printed in General Technical Report INT-313). (321)

White, C. A. ., Olmsted, C. E. , Kay, C. E. . 1998. Aspen, elk and fire in the Rocky Mountain national parks of North America. Wildlife Society Bulletin. 26 3: 449-462.

Across 6 Rocky Mountain parks aspen shows consistent responses to increased browsing by ungulates and decreased frequency of fire. Most stands are in decline. Aspen stands regenerate well in areas of low elk density and in some areas of moderate ek density, but in areas of high and very high elk density doesn't grow over 2 m. Burning accelerates clone deterioration. (322)

WATER

Boyle, T. P., and N.J. Hoefs, 1991, An Analysis of Factors Contributing to the Stability of Benthic Macroinvertebrate Communities in Lotic Ecosystems: Bulletin of the Ecological Society of America, v. 72, p. 74.

Structural and functional attributes of benthic macroinvertebrate communities have been used historically as indicators of water quality and biological criteria of the environmental health

of lotic systems. There has been little examination of the limitations or qualifications of what environmental conditions make it appropriate to use various attributes of the benthic macroinvertebrate community in environmental assessments. One goal of developing ecological risk analysis techniques is to be able to distinguish the natural uncertainty in bioindicators due to environmental conditions from those anthropogenically induced. Approaches to determine the variability of the macroinvertebrate community due to natural conditions will affect their use as an environmental assessment tool. Data on the macroinvertebrate communities from the Virgin River, Utah; St. Croix River, WI&MN; Niobrara River in NE; Platte River, Otter Creek, Shalda Creek and Crystal River in MI; and Wilson Creek, MO were analyzed for community characteristics suitable for analysis for environmental impact. Key characteristics of the physical and chemical environment such as patterns of hydrological discharge, substrate, organic loading, etc. were analyzed as natural forces shaping community structure in these different areas that determine the appropriateness and type of community analysis scheme to be used in different conditions. (Abstract by Boyle and Hoefs as printed in Bulletin of the Ecological Society of America). (656)

Brooks, K. N., P. F. Folliott, H. M. Gregersen, and L. F. DeBano. 1997. Hydrology and the Management of Watersheds. Second Edition. Iowa State University Press. Ames, Iowa. pp 502.

Abstract in Progress (323)

Clark, G. M. , et al. 1998. Water quality in the upper Snake River basin, Idaho and Wyoming, 1992-95. USGS.

Abstract in Progress (353)

Davis, J.C., G.W. Minshall, C.T. Robinson, and P.B. Landres. In press. Monitoring wilderness stream ecosystems. USDA Forest Service General Technical Report RMRS-GTR-21. Rocky Mountain Research Station, Ft. Collins, CO.

A protocol and methods for monitoring the major physical, chemical, and biological components of stream ecosystems are presented. The monitoring protocol is organized into four stages. At stage 1 information is obtained on a basic set of parameters that describe stream ecosystems. Each following stage builds upon stage 1 by increasing the number of parameters and the detail and frequency of the measurements. Stage 4 supplements analyses of stream biotic structure with measurements of stream function: carbon and nutrient processes. Standard methods are presented that were selected or modified through extensive field application for use in remote settings. (Abstract by Davis et al as printed in General Technical Report RMRS-GTR-70). (324)

Farnes, P.E., C. Heydon, and K. Hansen. 1999. Snowpack distribution across Yellowstone National Park, Wyoming. Final Report. Contract No. 291601. Yellowston Center for Resources, Yellowstone National Park, WY.

Data on snowpack distribution, snow depth and snow density, daily precipitation/snow water equivalent, daily temperature correlated with plant and animal responses. Data from National Weather Stations and NRCS SNOTEL stations; ca. 1948 on. Some data near realtime. Ca. 20 high elevation sites in YNP from which daily data is available. Has average monthly precipitation over 30 year span; differences by elevation. Info on maxiumum elevation of the Lake throughout this century; which has implications for bird nesting and trout spawning, etc.

Data helps in index of winter severity (IWS) for elk, bison etc. which relates to reproduction, mortality, predation. Use different weights for different species, but snow usually weighted most. Has table of effective critical temperatures (for bison, 29 below!). Determines forage production, drought index, growing degree days (GDD), and when plants can break dormancy. Some years there aren't enough gdds to mature grasses. Affects migration patterns. Can calculate SWE for any slope or aspect. With snow structure info can predict avalanche probability. Can predict crops of whitebark pine nuts, grizzly emergence from den. (325)

Gibert, J., D.L. Danielopol, J.A. Stanford (1994): Groundwater Ecology. Academic press, San Diego, California.

Abstract in Progress (327)

Heede, B. H. 1992. Stream Dynamics: an overview for land managers. USDA Forest Service General Technical Report RM-72.

Abstract in Progress (328)

Leopold, L. B. 1995. A view of the river. Academic Press, New York.

Abstract in Progress (331)

Lowry, M.E., H.W. Lowham, and G.C. Lines. 1976. Water resources of the Bighorn Basin, northwestern Wyoming. U.S. Geol. Surv. Hydrologic Investigations, Atlas HA-512. Reston, VA. 2 color maps.

Abstract in Progress (332)

Marston, R. A. , Anderson, J. E. . 1991. Watersheds and vegetation of the Greater Yellowstone Ecosystem. Conservation Biology. 5 3: 338-346.

This paper describes major watershed systems and broad patterns of vegetation within the Greater Yellowstone Ecosystem, explains the geographic links between these systems, and proposes factors that could be used to measure the integrity (condition and naturalness) of watersheds and vegetation. The Greater Yellowstone Ecosystem is the headwaters for three major continental-scale river systems: the Missouri-Mississippi, Snake-Columbia, and Green-Colorado. Features, processes, and materials of watersheds provide structure and key functions to ecosystems of Greater Yellowstone. Changes in elevation - and the accordant changes in precipitation, temperature, land forms, and the stream network - exert the strongest control on the distribution of plant species in the Greater Yellowstone Ecosystem. The condition and naturalness of watersheds and vegetation remain to be quantified, but both decline with distance away from the core of the Greater Yellowstone Ecosystem due to timber harvest, oil and gas exploration and development, mineral exploration and development, reservoir operations, flood control, agricultural development, and livestock grazing. (333)

Maupin, Molly A. 1995. Water-quality assessment of the upper snake river basin, Idaho and Western Wyoming-environmental setting, 1980-92. U.S. Geological Survey Water Resources Investigations Report 94-4221.

The 35,800-square-mile upper Snake River Basin is one of 20 areas studied as part of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey. Objectives of NAWQA are to study ground- and surface-water quality, biology, and their

relations to land-use activities. Major land and water uses that affect water quality in the basin are irrigated agriculture, grazing, aquaculture, food processing, and wastewater treatment. Data summarized in this report are used in companion reports to help define the relations among land use, water use, water quality, and biological conditions. The upper Snake River Basin is located in southeastern Idaho and northwestern Wyoming and includes small parts of Nevada and Utah. Total population in the basin was about 425,000 in 1990. Major urban areas are Idaho Falls, Pocatello, Rexburg, and Twin Falls, Idaho, which make up 10, 11, 3, and 6 percent of the total population, respectively. Climate in the basin is mostly semiarid and mean annual precipitation ranges from 8 to more than 60 inches. The eastern Snake River Plain is the major geologic feature in the basin and is delineated mostly by Quaternary and Tertiary basalt flows. It is about 55 to 62 miles wide and 320 miles long and bisects the basin in a northeast-southwest direction. The Snake River is the dominant surface-water feature and flows about 453 miles from the southern border of Yellowstone National Park in Wyoming to King Hill, Idaho, where it leaves the basin. The Snake River flows through river reservoirs that provide a total storage capacity of more than 4 million acre-feet. Gravity-flow diversions are predominant in the upper part of the basin and totaled 8.8 million acre-feet in 1980. Pumped diversions occur mainly in the lower part of the basin and totaled 08,500 acre-feet in 1980. The Snake River Plain aquifer is the predominant ground-water feature in the upper Snake River Basin and underlies the eastern Snake River Plain. The upper 500 feet of the aquifer may store 200 to 300 million acre-feet of water. Ground-water resources that supply agricultural lands are sustained by recharge from surface-water irrigation, precipitation, and tributary inflow. Major ground-water discharges are at springs and seeps of from ground-water pumpage for irrigation.
Water use in the basin is dominated by irrigated agriculture, which is the largest consumptive water use in the basin. Major crops in the basin include potatoes, wheat, sugar beets, hay, and barley. Most irrigation needs are supplied from surface-water sources through a series of canals and laterals. In 1990, about 2.5 million acres were irrigated with more than 14.2 million acre-feet of surface and ground water. About 21 percent of the basin is agricultural land and 50 percent is rangeland. Idaho leads the Nation in trout production for commercial sale. Combined mean annual discharges from 12 aquacultural facilities in the basin (1985-90) were about 787,000 acre-feet. These facilities are clustered in a reach of the Snake River between Milner Dam and King Hill where ground-water discharge is from many seeps and springs that provide sufficient quantities of good-quality water. Other facilities that release effluent to the Snake River include 13 municipal wastewater treatment plants and 3 industrial facilities. (Abstract by Maupin as printed inWater-Resources Investigations Report 94-4221). (661)

Minshall, G. W. , Brock, J. T. . 1991. Observed and anticipated effects of forest fire on Yellowstone stream ecosystems. Pages 123-136 in Keiter, R. B. , Boyce, M. S. . The Greater Yellowstone ecosystem: redefining America's wilderness heritage. Yale University Press, New Haven.

Abstract in Progress (666)

Norton, D., Friedman, I., 1991. Chloride flux and surface water discharge out of Yellowstone National Park, 1982-1989: U.S. Geol. Surv. Bull. 1959, 42 pp.

Chloride flux was calculated by the product of discharge and chloride concentration for the major rivers draining the Park. Large annual changes occur attributed to changes in height of the water table caused by variations in precipitation. (336)

Peterson, D.A. And S.D. Porter. 2002. Biological and chemical indicators of eutrophication in the Yellowstone River and major tributaries during August 2000. Proceedings: 2002 National Monitoring Conference, National Water Quality Monitoring Council.

The trophic condition of the Yellowstone River and its major tributaries during low-flow conditions was better represented by algal biomass and community autecology than by nutrient concentrations in water samples. Nutrient concentrations generally were low throughout the length of the Yellowstone River, however indicators of algal biomass and the percentage of eutrophic and nitrogen-indicator diatoms were relatively high in the middle segments of the river and near the mouths of major tributaries. Algal biomass and community composition were influenced by the availability of nitrogen and water turbidity. Biomass increased with the abundance of eutrophic taxa, and was relatively small at sites dominated by nitrogen-fixing blue-green algae. Eutrophication of streams and rivers in the Yellowstone River basin is influenced by nitrogen inputs from human sources along the river corridors and within the watershed. Algal community indicators can provide an early warning of accelerated eutrophication processes, long before nuisance algal growths contribute to water-quality problems. (Abstract by Peterson and Porter as printed in 2002 National Monitoring Conference Proceedings). (660)

Plafcan, M., E.W. Cassidy, and M.L. Smalley. 1993. Water resources of Big Horn County, Wyoming. U.S. Geological Survey Water-Resources Investigations Report 93-4021. 142 pp.

Ground water in unconsolidated aquifers is the most reliable and accessible source of potable water in Big Horn County, Wyoming. Well yields generally ranged from 25 to 200 gal/min (gallons per minute), however, yields of 1,600 gal/min are reported from wells in the gravel, pediment, and fan deposits. Bedrock aquifers that yield the most abundant water supplies are the Tensleep Sandstone, Madison Limestone, Bighorn Dolomite, and Flathead Sandstone. The aquifers with the most potential for development as a water supply, predominately composed of sandstone, are the Lance, Mesaverde, and Frontier Formations. The Madison Limestone, the Darby Formation, and the Bighorn Dolomite form the Madison-Bighorn aquifer. Reported yields from the aquifer ranged from 40 to 14,000 gal/min. Flowing wells from the Madison-Bighorn aquifer had shut-in pressures ranging from 41 to 212 pounds per square inch (95 to 490 feet above land surface).

Shut-in pressures from flowing wells in bedrock indicate declines, from the time the wells were completed in 1988, as much as 390 feet. Flows have also decreased over time. Water samples from wells completed in unconsolidated aquifers have concentrations of dissolved solids less than 2,000 mg/L (milligrams per liter). Water from unconsolidated aquifers are classified as a calcium sulfate type, a sodium type, and sodium-calcium sulfate type. Water samples from well completed in aquifers in Paleozoic and Precambrian rocks had median concentrations of dissolved solids ranging from 111 to 275 mg/L. Water samples from wells in Tertiary and Cretaceous rocks had a medium concentration of dissolved solids raging from 1,107 to 3,320 mg/L. Water types from these aquifers were usually sodium sulfate. Perennial streams originate in the mountains and ephemeral streams originate in the Bighorn Basin. Irrigation return-flow to streams maintains perennial flow in what would otherwise be ephemeral streams. Streams that originate in the Bighorn Basin have specific conductance values generally greater than 1,000 mg/L, whereas streams that originate in the Bighorn Mountains have specific conductance values generally less than 1,000 mg/L. The predominant dissolved constituents are calcium or sodium and bicarbonate or sulfate. Concentrations of pesticides detected in surface-water samples were less than the U.S Environmental Protection Agency (USEPA) maximum contaminant levels. The detected concentration of pesticides in streambed material in the organochlorine insecticide class ranged from 0.1 to 8.0 micrograms per kilogram. Pesticides detected in ground-water samples included dicamba and picloram at a concentration of 0.40 ?g/L (micrograms per liter), atrazines (0.40 ?g/L), aldicarb sulfone (1.44 ?g/L), aldicarb sulfoxide (0.52 ?g/L), and malathion (0.02 ?g/L). Analyses of ground-water samples for radionuclides indicate that concentrations from four municipal wells exceeded the maximum contaminant level established by the USEPA. Of these four wells, concentrations in water samples from the municipal well at Frannie consistently exceeded the USEPA maximum concentration level for dissolved gross alpha activity of 15 pCi/L (picocuries per liter) and radium-226 plus radium-228 (5 pCi/L). The source of the radioactivity is postulated to be the Madison Limestone. Surface water accounts for 96 percent and ground water accounts for 4 percent of total offstream water use in Big Horn County, Wyoming. Irrigation is the largest offstream use of both surface and ground water. About 99 percent of offstream surface water and 55 percent of ground water is used for irrigation. Eighty-two percent of the water used for irrigation is consumed, which includes a 37-percent conveyance loss and 45 percent consumed by the irrigated crops. Ground water supplies 89 percent of water used for domestic purposes and about 16 percent of water used for public supplies, which shows that ground water is a primary domestic water supply in rural areas where public supplies are not available. (Abstract by Plafcan et al. As printed in Water resources of Big Horn County) (664)

Robinson, C.T. and G.W. Minshall. Physical and chemical responses of streams in Yellowstone National Park following the 1988 wildfires. In: Greenlee, J. ed. 1996. The ecological implications of fire in Greater Yellowstone: Second biennial conference on t

Study examined 5 years of change in physical and chemical properties of 21 stream sites differently affected by the 1988 fires. Degree of physical change was assessed using summed Coefficients of Variation. (668)

Stanford, J.A. and John J. Simons (Eds.). 1992. Proceedings of the First International Conference on Ground Water Ecology. American Water Resources Association, Bethesda, MD. 420pp.

Abstract in Progress (340)

Thorpe, J., and A. Covich, editors. 1991. Ecology and Classification of North American freshwater Invertebrates. Academic Press, Inc., NY. 911 pp.

Abstract in Progress (341)

Turk, J.T. and N.E. Spahr. 1991. Rocky Mountains: controls on lake chemistry. In: D.F. Charles, ed. Acidic Deposition and Aquatic Ecosystems. Regional Case Studies. Ch 14:471-503. Springer Verlag, New York.

Abstract in Progress (342)

Winter, T.C., J.W. Harvey, O.L. Franke, and W.M. Alley. 1999. Ground water and surface water-a single resource. U.S. Geological Survey Circular 1139. 77 pages.

Abstract in Progress (659)

Wolman, M. G. and J. P. Miller. 1960. Magnitude and frequency of forces in geomorphic processes. Journal of Geology. 68: 54-74.

The relative importance in geomorphic processes of extreme or catastrophic events and more frequent events of smaller magnitude can be measured in terms of (1) the relative amounts of "work" done in the landscape and (2) in terms of the formation of specific features of the landscape. For many processes, above the level of competence, the rate of movement of material can be expressed as a power function of some stress, as for example, shear stress. Because the frequency distributions of the magnitudes of many natural events, such as floods, rainfall, and wind speeds, approximate log-normal distributions, the product of frequency and rate, a measure of the work performed by events having different frequencies and magnitudes will attain a maximum. The frequency at which this maximum occurs provides a measure of the level at which the largest portion of the total work is accomplished. Analysis of records of sediment transported by rivers indicates that the largest portion of the total load is carried by flows which occur on the average once or twice each tear. As the variability of the flow increases and hence as the size of the drainage basin decreased, a larger percentage of the total load is carried by less frequents flows. In many basins 90 per cent of the sediment is removed by storm discharges which recur at least once every five years.

Transport of sand and dust by wind in general follows the same laws. The extreme velocities associated with infrequent events are compensated for by their rarity, and it is found that the greatest bulk of sediment is transported by more moderate events.

Many rivers are competent to erode both bed and banks during moderate flows. Observations of natural channels suggest that the channel shape as well as the dimensions of meandering rivers appear to be associated with flows at or near the bankfull stage. The fact the bankfull stage recurs on the average once every year or two years indicates that these features of many alluvial rivers are controlled by these more frequent flows rather than by the rarer events of catastrophic magnitude. Because the equilibrium form of wind-blown dunes and of wave-formed beaches is quite unstable, the frequency of the events responsible for their form is less clearly definable. However, dune form and orientation are determined by both wind velocity and frequency. Similarly, a hypothetical example suggests that beach slope oscillates about a mean value related in part to wave characteristics generated by winds of moderate speed. Where stresses generated by frequent events are incompetent to transport available materials, less frequent ones of greater magnitude are obviously required. Closer observation of many geomorphic processes is required before the relative importance of different processes and of events of differing magnitude and frequency in the formation of given features of the landscape can be adequately evaluated. (Abstract by Wolman as printed in Journal of Geology). (343)

Young, H.W., Parliman, D.J., Jones, M.L., and Stone, M.A.J., 1991, Hydrologic and water-quality data for selected sites, Grand Teton National Park, Wyoming, September 1988 through September 1990: U.S. Geological Survey Open-File Report 91-0056, 23 p.

This report presents data collected from 13 observation and 10 production wells in and near Grand Teton National Park, Wyoming, from September 1988 through September 1990. The data include measurements of depth of well, depth to waterm and analyses of selected water-quality characteristics. These data were collected as part of a continuing monitoring program being conducted in cooperation with the National Park Service. (Abstract by Young et al as printed in USGS Open File Report 91-56). (344)

WILDLIFE

Aguirre, A. Alonso, Starkey, Edward E. 1994. Wildlife Disease in U.S. National Parks: Historical and Co evolutionary Perspectives. Conservation Biology. 8 3: 654-661.

Diseases of wildlife have significant management implications in a number of lands of the U.S. National Park Service due to increasing interactions between wildlife and domestic animals. We review the paleontology, history, and coevolution of infectious diseases in North American ungulates. We provide two examples related to bovine brucellosis in bison in Yellowstone and lung-worm-pneumonia complex in bighorn sheep in several western national parks. These examples illustrate the difficulty of managing wild populations and their diseases in national parks and other protected areas. In some instances, human intervention may be justifiable in order to protect native populations, domestic animals, and humans from acquiring a disease. (348)

Bohac, J., and R. Fuchs. 1991. The structure of animal communities as bioindicators of landscape deterioration. Pp. 165-178 In D. W. Jeffrey and B. Madden (eds.) Bioindicators and Environmental Management. Academic Press, London, England, UK.

Biodiagnostic evaluation methods were developed during the five years 1986-1990. Biodiagnostic investigations are made on a range of life forms and at various scales. They are performed both at population and community level. The data on plants and animals must e obtained at the appropriate scale of the investigation (local, regional, fluvial). Biomonitoring at regional and fluvial scales is mainly by using populations of small mammals and communities of birds. These groups, owing to their large size and migratory birds, are optimal bioindicators of the complex of factors which degrade the landscape and lead to air pollution. Populations and communities of invertebrates are mainly used for biomonitoring at a local scale. These groups have small body sizes and a lower tendency for migration, and are therefore suitable for indicating local environmental factors such as unsuitable application of fertilizers and pesticides, unsuitable methods of landscape management, overdrainage and the consequential desiccation of the landscape. Biomonitoring at the local scale is often the sole method for the investigation of biotic conditions in reserves and national parks. The investigation of key organisms and their communities in portions of the landscape is important for the research at the regional scale. The mosaic of various well-preserved landscape units increases the stability of the landscape. (Abstract by Bohac as printed in Bioindicators and Environmental Management). (349)

Coleman, S. . 1995. Disease research and monitoring of Yellowstone's wildlife. Investigator's Annual Report.

primarily bison to begin with (350)

Consolo-Murphy, S., and K. Murphy. 1999. Wildlife at Yellowstone: the story behind the scenery. K.C. Publications, Inc., Las Vegas, Nev. 64 pp.

Abstract in Progress (351)

Olliff, T., K. Legg, and B. Kaeding, eds. 1999. Effects of winter recreation on wildlife of the GYA: a literature review and assessment. Report to the Greater Yellowstone Coordinating Committee. Yellowstone National Park, Wyoming. 315 pp.

Abstract in Progress (665)

Ream, C. H. . 1980. Impact of backcountry recreationists on wildlife: an annotated bibliography. General Technical Report INT-84.

An annoted bibliography and evaluation of the literature on the effects of backcountry recreationalists on wildlife. Literature was taken from biological, managerial, sociological, and popular publications. Orientation includes decriptions of impacts and methods of reducing impacts of recreationists on wildlife. (Research summary by Ream as printed in GTR-INT-84). (352)